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Current Problems in the Sensitometry of Color Materials and Processes

By Franklin C. Williams

The methods of sensitometry of color materials and processes are specialized developments of the methods of black-and-white sensitometry. The nature of the individual material and its intended use govern the specifications of the operations of exposing, processing, density measurement, and interpretation of results. Apparatus and techniques now available are adequate for important applications of sensitometry in the manufacture and use of color materials. Current research is refining existing methods of sensitometric investigation and yielding more significant test results.

Interest in the sensitometry of color materials and processes has grown rapidly in the motion picture industry, especially as the film user rather than the film manufacturer has become involved in processing, printing and other laboratory phases of color-film production. In laboratory operations involved in production of black-and-white motion pictures, sensitometric methods have found important uses. It is reasonable to expect that similar or even greater benefits from their use may be found in work with color motion pictures. Certainly, color-film manufacturers have found color sensitometry useful to the point of necessity. Sensitometric methods of investigation and control have played an essential part in the development, production and processing of the wide variety of sensitized color materials which are now available. The extent to which the usefulness of color sensitometry can soon be broadened is indicated by certain aspects of the present state of the science and by developments which are now in progress. It is the intent of this paper to present a brief view of this state, and of certain current developments, with respect to activities in the plants and laboratories of the Eastman Kodak Co.

The general purpose of sensitometric investigation is the establishment of useful relationships among the elements of the chain of operations which result in a photographic image; or rather, finally, to relate the elements of image formation to the impression which the photographic image forms in the mind of the observer. Sensitometric tests usually are required to show how the quality of an image is dependent on exposure, on processing, or on the characteristics of the materials used. The re-

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Communication No. 1361 from the Kodak Research Laboratories, a paper by Franklin C. Williams, Research Laboratory, Eastman Kodak Co., Kodak Park Works, Rochester 4, N.Y. It was read by Dr. W. T. Hanson, Jr., of Eastman Kodak Co. on October 11, 1949, at the Society's Convention in Hollywood, Calif.

lationships among these and other elements are described in terms of physical quantities. Sensitometry must, therefore, provide accurate and practical means of making the required physical measurements. It must also select and specify what kind of measurement should be made in order that the results be most significant. It must further provide systematic interpretation of the results. Not all of these things can be done at once. To date, development of the science of color sensitometry has emphasized specification of a few basic kinds of measurement, and development of accurate and dependable means of making them. Only during the past few years has vigorous development of systematic interpretation of the results of these measurements been under way.

In order that sensitometric testing be practical, a further requirement must be recognized: The test must be simple. It is for this reason that so much of the sensitometry of black-and-white materials has been reduced to relationships between log exposure and image density. This relationship, usually expressed in the classic curve of Hurter and Driffield, which is itself a model of simplicity, is derived from an irreducible minimum of straightforward operations—exposure, processing and determination of image density. A surprisingly complete knowledge of the photographic properties of a film can be derived from such a test if it is properly specified and conducted. It is natural that similar tests should be tried as the basis of the sensitometry of color materials and processes. Such trials have been adequately successful, so that most of the procedures of color sensitometry that are now in use are special adaptations of procedures originally successful in the sensitometry of black-and-white materials.

This adaptation of the procedures of the sensitometry of black-and-white materials has required throughout careful examination and usually extensive revisions of the specification of each element of sensitometric operation. Furthermore, particularly in specifying the objectives of density measurement, new concepts have had to be developed. A review of these revisions, developments and some of the problems of color sensitometry can be made by examining the elements of routine testing procedure in the order of their occurrence.

Sensitometric Exposures

Since exposure of the film is the first step of the routine, first met are problems of knowing and of specifying what test exposures should be made, and how to make them. The images of color films are, of course, sensitively dependent upon the quality of the exposing light. In color-film testing, therefore, that quality must be extremely well controlled. It must also be carefully chosen. In the film plane of a camera, a different quality of light exists at least at every differently colored point of the image. The response of the film to every one of these different qualities of light may be important. No one quality of light, therefore, can possibly furnish a complete test of the color-reproducing abilities of the film. An infinite set of qualities would be required. But in attempting to reduce tests to forms which are both simple and significant, effort is continuously applied toward specifying, for routine tests, a small number of test colors which may test the film adequately. The exposing-light qualities which represent these colors are generally chosen for one, or both, of two purposes. Some colors are used because they, and therefore their reproductions, are pictorially important. Tests using these colors give directly specific but limited information about the color-reproducing abilities of the film. Other exposures may not represent picture elements at all, but are chosen to give basic information about exposure-image relationships. From these relationships,

the sensitometrist can determine indirectly certain general information about the color-reproducing abilities of the film.

In sensitometric testing, both kinds of exposure are regularly used. Use of exposures which permit product appraisal by direct physical or psychophysical measurements of color reproduction has recently been considerably improved. Work by Brown, MacAdam,[1] and others is extending the data of color discrimination in relationships involving both chromaticity and luminance. This is essential if we are to make quantitative comparisons of color reproductions under practical conditions, which generally involve approximations in both chromaticity and luminance. In the Eastman Kodak Co.'s Color Control Dept., a research group working under R. M. Evans is engaged in the study of the psychophysical and psychological factors involved in the perception of colored objects. Their findings are giving us a much better understanding of the influences of these factors in the evaluation of color reproduction fidelity. Valuable data on the relative photographic importance of colors are coming from statistical analysis of the subject content of customers' pictures. Although the results of these researches have as yet been applied only to product-development work, they will soon find their way into routine testing procedures.

Eventually, the reproduction criteria arising from such work will permit systematic choice of the second kind of test colors—those which may not be critically important in themselves but which will provide sensitive and significant indicators of general reproduction quality. With one exception, these colors cannot yet be chosen systematically. The exception is the color gray. Although the intrinsic importance of accurate reproduction of gray is debatable, a "gray-scale test" is a routine procedure in sensitometric testing of practically every kind of color film made. Years of testing have shown that it is a dependable, sensitive indicator of many important features of the color reproduction characteristics of a film.

A sensitometric gray scale on a color film is the result of exposing the film to a series of intensities of white light. The gray-scale exposure, therefore, must be made with the kind of light which white or gray objects place on the film under conditions of normal use. More exact definition describes the white or gray objects as spectrally nonselective, diffusely reflecting objects. Specifying the conditions of "normal use" requires some investigation of the radiant energy source and of spectrally selective factors in the photographic system.

For example, in exposures made with artificial light, the quality of light in gray-object images is primarily determined by the original source, such as a tungsten lamp, but it is also importantly affected by spectral selectivity of the reflectors and lenses of the lighting units and by selective absorption in the camera lens. It cannot properly be simulated in the laboratory by simply matching the energy distribution of the unmodified lamp source. A special lamp-filter combination is required. Similarly, in exposures made with natural daylight, the white-light quality is dependent upon several factors. These include the position of the sun, the portion of sky effective as illuminant, the atmospheric conditions prevailing throughout the sky, the orientation of the subject with respect to the sky, the degree and nature of reflections by nearby objects, flare light, lens absorptions and other minor factors. The design of sensitometer light sources must include consideration of these factors. We now have good approximations for some of the required light qualities; these include artificial daylight and sources duplicating tungsten lighting qualities. But the newer light sources

in use in motion picture practice and elsewhere are difficult to match in a sensitometer, especially since sensitometer sources must be stable and adequately powerful as well as spectroradiometrically correct. This problem is receiving considerable attention. For its solution, better spectroradiometric data are required than are now available, and an instrument for this purpose is under construction in our laboratory.

The actual exposure of film to the light quality selected can be made in sensitometers already developed for sensitometry of black-and-white materials. The great importance in color sensitometry of making the exposure represent normal conditions of time and intensity, in order to avoid errors arising from failure of the reciprocity law, has led to development of special models of this apparatus, but no radically new principles have been introduced.

Sensitometric Processing

The second set of problems in color-film sensitometry is met in the processing of the sensitometric test films. It has long been a first principle of sensitometric practice that the processing of test samples must satisfy two requirements: It must be repeatable with excellent precision, and it must be correct in kind. Probably no requirements of sensitometric color testing are more difficult to meet than these. Correct and invariable sensitometric color processing is difficult, but where such processing must be done, it is being done; frequently there is no really acceptable alternative course. Improved methods of using production processes for sensitometric tests are constantly under development, and improvement has been made, especially in treatment of the data, but variable processing can be used for evaluation of film characteristics only by making some sort of repeated comparison with one or more selected "check" films, simultaneously processed to furnish a basis of reference. This familiar procedure offers a frequently useful substitute for direct measurement but also a somewhat treacherous one, since an adjustment based on one process-film combination often is not applicable to another. Modern methods of statistical analysis furnish means of recognizing such cases in a properly designed experiment, but not of correcting the data.

The application of advanced statistical methods to interpretation of sensitometric data is a course of development in color sensitometry which deserves early recognition. Statistical methods are receiving wide recognition in industry as a tool especially useful in handling processes of complex variability. In color photography, known variables rarely can be made to operate with complete independence. It is possible, however, by special statistical methods, to extract from complexly variable data significant descriptions of the individual variations. The methods have been reduced to routine forms and are proving of great value in both research and testing operations.

A process which is repeatable but incorrect also presents difficulties. If the testing process does not accurately represent the normal treatment of the film, appraisal of the product is at least uncertain and is sometimes impossible either by direct measurement or by comparison with a "check" film. Furthermore, considerable experimental evidence indicates that the best, and quite possibly the only, adequate method of maintaining long-time stability in characteristics of film and processing, each independent of the other, is a combination of a stable reference process and extensive chemical analysis. Sensitometric color processing, therefore, is the subject of much research activity. The research involves both special processing apparatus and special processing solutions.

In sensitometry of materials for black-and-white photography, there has

Fig. 1. Automatic machine for processing sensitometric test strips of color films and papers.

been adequate demonstration of the value of processing equipment especially designed for sensitometric testing. The reciprocating-paddle machine described by Jones, Russell and Beacham[2] has been notably successful in providing repeatable processing with excellent uniformity in its treatment of all samples in a particular loading. The principles of this machine have been applied to color processing with good success. Considerable enlargement of the equipment is, however, necessary to make color-processing output comparable with the usual output of black-and-white film. For example, one kind of sensitometric color-processing machine in use in the Film Testing Dept. at Kodak Park is shown in Fig. 1. These machines contain eleven developing tanks and eleven wash tanks; the machines for developing black-and-white film contain only one of each. In the color-film processing machine, the test samples, on racks, are placed in light-tight developing units which are lowered by motor into the tanks. Each machine is equipped with three such developing units. Each unit has an independent set of paddles and an associated drive. The unit of film, paddles and drive travels the length of the machine on an overhead track, then circles back to the starting end for reuse. Each unit carries with it a battery of 22 clock-driven controllers which automatically govern the sequence and duration of the process operations. The degree of agitation, electronically controlled, is widely variable and also is

automatically selected by the controlling panel. The three units, each holding 80 sample strips and operating independently, are spaced far enough apart in the machine to let the operator change processing solutions between units. It is therefore possible to process Kodachrome, Ektachrome and Ektacolor films simultaneously on the same testing machine.

Smaller machines with fewer automatic features are useful in process control if they are designed to provide precisely controlled development. Several such machines have been built and have proved capable of producing processes of good repetition accuracy. It is realized, however, that no sensitometric processing machine yet designed is ideal, particularly in its ability to imitate color processing as done in large continuous film-strip machines. Further improvements along this line are necessary.

The processing machine is no more important than the solutions which go into it and is much more easily made free of undesirable variation. Sensitometric processes must be repeatable not only from day to day, but, if necessary, from year to year. Such repetition can be guaranteed only by identical handling of the film in solutions of identical chemical constitution. A good processing machine will provide identical handling. A perfectly replenished continuous process would provide the identical processing solutions, but, although recent improvements in analytical methods promise to guarantee nearly perfect replenishments, this method has not been entirely satisfactory in sensitometric work. Instead, repeated identity of processing solutions has been accomplished by using, for each test, entirely new solutions mixed from a homogeneous reserve stock of chemicals.

The attainment of chemical identity in processing solutions is not a simple matter. Some solutions used in color processing are sensitive to extremely small changes in amount of ingredients and to variations in mixing procedure. So small a thing as the way in which a dry chemical is poured into the solution can materially affect the sensitometric result. We have found, for example, improved repetition precision when the alkaline ingredients of the solutions are dissolved in nearly the ultimate solution volume, before any oxidizable ingredients are present; otherwise, the amount of oxidation in the high pH region immediately surrounding the dissolving alkali will vary objectionably from batch to batch. Small-volume mixing requires precision weighing, frequently with analytical balances, and liquid measurement with volumetric pipettes. If precision of chemical measurement and handling is adequate, repeatable mixes in one-gallon batches are possible in apparatus like that shown in Fig. 2, a jacketed cone with high-speed turbine homogenizer. It is preferable, however, to mix in larger batches wherever possible. Large-batch mixing is economically feasible only if the solutions can be stored, without deterioration, for later use. We have found that chemical solutions can be stored successfully by segregation of reactive components, and in difficult cases have found it helpful to store solutions just above their freezing point. Tests made throughout the past year have shown that even coupler-developer solutions can be made to maintain unchanged properties for at least three weeks.

When the film samples of a sensitometric test have been exposed and processed, the testing routine requires next that their image densitities be determined. We recognize in color densitometry two classes of density measurement with two distinctly different purposes: One class is called integral densitometry; the other, analytical densitometry. The purpose of integral densitometry is the measure-

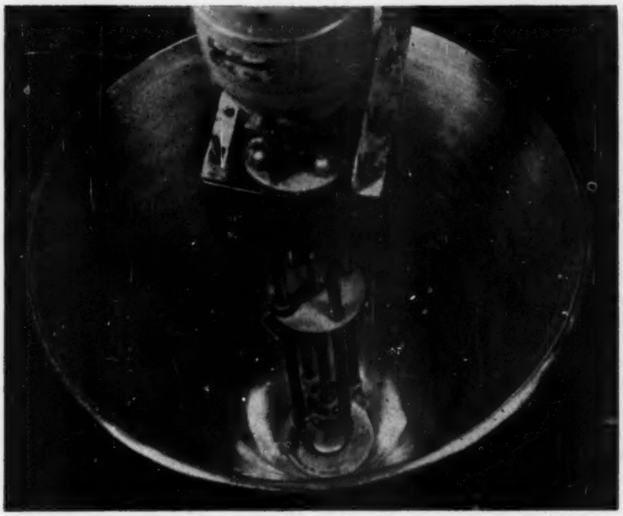

Fig. 2. Jacketed conical mixing vessel and turbine homogenizer for mixing small batches of color-film processing solutions.

ment of the composite, multilayer image to determine some total action, some particular effectiveness of the integrated image absorptions. The purpose of analytical densitometry is the determination of the individual densities of certain components of the image, such as the densities of the individual yellow, magenta and cyan dyes.

Printing Densities

In the sensitometry of color materials to date, the most valuable integral densitometry has been the measurement of printing densities. A color negative, for example, may be printed on a color-print film that has a red-sensitive emulsion, a green-sensitive emulsion, and a blue-sensitive emulsion. The function of the negative is the regulation of the amount of exposure of each of these emulsions. The negative performs this function by absorbing some of the light which would expose these red-, green- and blue-sensitive emulsions. The amounts of the absorptions can be expressed as densities called "printing densities." Since the negative image will usually absorb red, green and blue light unequally, it will have three different printing densities. Each step of a gray scale will, therefore, have three printing densities, and, if these are plotted as a function of log exposure, the gray scale produces three characteristic curves. These are called the "gray-scale printing-density curves." A set of such curves is shown in Fig. 3.

The determination of printing densities by a densitometer requires the use of precisely specified kinds of red, green and blue light. The fundamental requirement is that the printing-density densitometer assign to radiant energies of various wavelengths the same relative importances that would be assigned by the printing system, that is, by the combination of printer light and

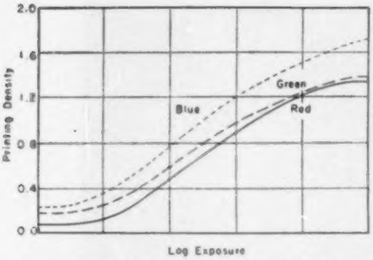

Fig. 3. Printing-density curves of the gray scale of a color-negative material.

print material. In a simple case, if only light of λ 680 mμ were effective in making a red-light print, the printing density of the negative would have to be determined by measurement with only light of λ 680 mμ. In most practical cases, energy of a particular spectral distribution throughout a more or less broad band is effective in printing, and this distribution must be accurately reproduced in the density-measuring instrument. Since the densitometer must determine three printing densities of each image, measuring energy of three such distributions must be readily available. In achieving these distributions, we have thus far managed to obtain adequate accuracy by using optical filters of specially designed transmittance functions. Printing densities so determined have become extremely valuable in product development and control. They are the principal sensitometric measurements used in performance inspection of color-negative materials. For this use, high-speed automatic densitometers have been developed. Figure 4 shows a recent model. Recently, the severe requirements imposed by colored coupler-negative materials have made the design of densitometer filters especially difficult and, as a result, research has been accelerated on the use of other means of spectrum selection. An obvious but difficult means is by disper-

Fig. 4. Automatic recording densitometer for rapid determination of printing densities.

sion of the energy of the densitometer light source into a spectrum image, selection of part of this spectrum by a mask, recombination of the transmitted portion into a homogeneous mixture and use of this energy for the measurements. We have had an instrument of this type under development for several years. The difficulties of obtaining simultaneously the excellent spectral purity and considerable energy required in the measuring beam are quite severe.

Analytical Densities

In some kinds of sensitometric work, image description by means of integral densities is inadequate. Especially in product development and in control of manufacturing and processing is knowledge of the individual dye densities of color images important. In such work, the desired characteristics of a color-film image can be expressed either by specifying its integral densities or by specifying the required densities of its component dyes. If specification is by integral densities, an obtained image can be compared with the desired image by integral densitometry, but, although this will describe the practical effects of any differences, it will not describe the differences in a way that indicates where to apply corrective measures. Wherever means are known by which individual dye deposits can be changed by known amounts in the process of image formation, approaches to the desired image characteristics are made most efficiently if the desired and obtained images are both described in terms of the individual dyes. Such a description is obtained by analytical densitometry and usually consists of a set of equivalent neutral densities. Equivalent neutral density is a unit for systematically expressing the densities of the individual dyes of a subtractive process in terms of their abilities to form grays. As defined by Evans,[3] the equivalent neutral density of a dye deposit in a subtractive color process is the density of the gray that would be formed by adding to that dye deposit the just-required amounts of the other dyes of the process. Figure 5 shows a set of equivalent neutral-density curves. Evans described an instrument for determining equivalent neutral density, but other methods have since been developed for faster determination, less subject to an operator's judgment.

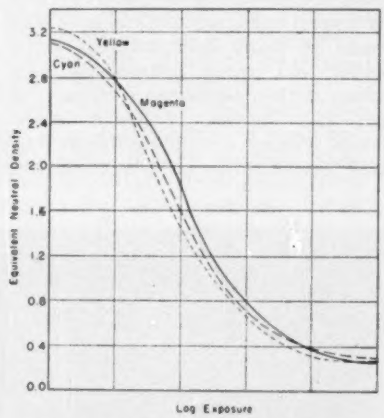

Fig. 5. Equivalent neutral-density curves of the gray scale of a professional sheet-film material.

One method, first described by Heymer and Sundhoff[4] in Germany, has been developed by the Film Testing Dept. in Kodak Park to a point that permits high-speed measurement. It requires an instrument that provides two identical light beams; the sample, in one beam, is synthetically matched by a combination of dye wedges in the other beam. A recent model is shown in Fig. 6. This model automatically makes all adjustments required in the analysis. The theory of analysis with instruments of this type involves fewer simplifying assumptions and approximations than are involved in other methods, but the cost of the instrument is high. Research

in the Kodak Laboratories has been directed toward the development of simpler means of analysis, particularly of one in which the required measurements are densities of the image determined by use of three narrow bands of light, one each in the blue, green and red spectral regions. By a system of coordinate transformation, these three integral densities are made to yield the required equivalent neutral densities. Instruments capable of measuring the integral densities are made commercially by several manufacturers and have been made by many sensitometrists themselves, but these instruments vary widely in their performance characteristics and abilities. Different instruments produce not only different integral density values but also conflicting analytical density values. This condition may be improved by activity of a committee of the American Standards Association which is attempting some standardization of color densitometry. In our laboratory, we use a densitometer of our own design and perform the coordinate transformations by a specially designed electrical analog computer, shown in Fig. 7. Integral density values are placed in it by setting three potentiometer dials. Closing one of the switches in the lower right-hand corner completes a circuit which instantly computes the equivalent neutral-density value of the cyan dye and activates a servo mechanism which rotates the central upper dial to the correct equivalent neutral-density figure. Upon opening the first switch and clos-

Fig. 6. Automatic analytical color densitometer.

ing a second, the magenta equivalent neutral density replaces the cyan-density figure; a third switch causes the yellow equivalent neutral density to appear. Accuracy of the computed transformed density value is better than 0.01.

In this work, as elsewhere in color sensitometry, the elementary theory is simple, but improvements past the elementary point involve labor among complex phenomena. A great deal of recent research on improvement of color-density measurements has been concerned with determining the real significance of image-analysis data. An essential step in this investigation is the derivation of an accurate spectrophotometric description of the minimum set of variables which can be combined to reproduce not only all the colors of which the process is capable but all the spectrophotometric distributions as well. Mathematical procedures for handling this problem have been developed. The analytical components so determined are being used in a study of product and processing variations to determine whether present methods of analysis yield the most significant data possible.

The fact that this work is being done is evidence that development of color sensitometry even now is growing out of its first stage, in which emphasis has been placed on the improvement of precision and accuracy of measurement. It is passing into the next phase, in which measurements, made with techniques of adequate precision and accuracy already achieved, are to be applied to more significant tests. Progress is being made toward the day when sensitometric methods may be as definitive in the specification of color-film quality as they are in the specification of quality of materials for black-and-white photography. That day has not yet come, but a great deal of progress has already been made.

Present-day tests are valuable tests. They require precise application of a carefully chosen exposure, a correct, precisely controlled color process, and densitometry by an accurate, rapid instrument which measures a specific kind of density particularly suited to derivation of significant information. By use of these solidly founded elements, it is possible to draw sensitometric curves on which we can make significant, though still experimental, measurements of contrasts, gradients, speeds, densities, exposure latitude and other important features of the material. These things are being done hundreds of times every day, furnishing information which is reliable and definitive.

Color sensitometry, therefore, stands now in a solid position of usefulness, with a good deal of accomplishment already behind it. Its immediate problems are those of improvement and exploitation of demonstrated techniques while pursuing a background development of new methods. The course of development will, in the near future as in the past, be considerably influenced by the demands of new products and new applications.

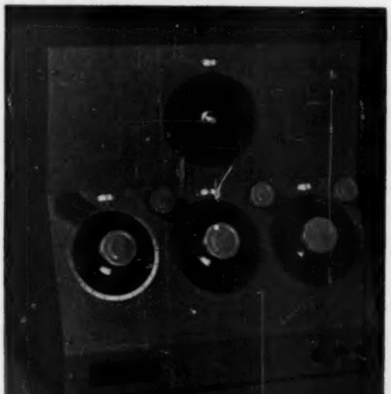

Fig. 7. Electrical analog computer for determining equivalent neutral densities from narrow-band integral densities.

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Discussion

Dr. Gundelfinger (Chairman of the Session), to Dr. Hanson who delivered Mr. Williams's paper: Doctor, I might just point out one thing. I believe that densitometer wedges must consist, must they not, of the same components that are used in the color processes?

Dr. Hanson: Yes, they must be composed of those components that are used in the process.

Dr. Gaspar: Is the power-type agitation the generally adopted method?

Dr. Hanson: Yes, that is true. Both of the machines that are shown in the slides have paddle-type agitation. In both machines the paddles are variable in speed and in the larger machine, in pitch, so the distance from the surface of the film to the paddle may be varied.

Dr. Gaspar: Do they move parallel to the film?

Dr. Hanson: They move across a 35-mm film. I might add that the general type of machine that has been used has been described by Jones, Russell and Beacham in the Society's Journal [ref. 2 above].

A Direct-Reading Equivalent Densitometer

By A. F. Thiels

The definition of equivalent density of a primary color of a multilayer color film is given and a direct-reading photoelectric equivalent densitometer is described. The method of operation of the instrument is explained and the basic features of the electronic circuit and the optical and mechanical layouts are given. The apparatus has made it possible to make direct measurements of the density of any one primary color of a color film without being affected by the presence, if any, of other primaries.

PRESENT-DAY COLOR FILMS consist principally of three emulsion layers in each of which, after exposure and color development, a color is formed: yellow in the blue-sensitive top layer, magenta in the green-sensitive middle layer and blue-green (cyan) in the red-sensitive bottom layer. These are called primary colors and will be referred to as follows:

j, yellow*
m, magenta
c, cyan (blue-green)

In the subtractive color composition practically all color variations can be reproduced by varying the relative proportions of the color density of the primary colors. In order to measure these color quantities in the sensitometry of color film, the equivalent density precept has come into current use.[1,2]

The equivalent density of a primary color is the neutral density which is obtained when the required quantities of two other primaries are added to the primary color to form a visually neutral gray. The determination of equivalent densities is therefore always linked to a selection of three primary colors, and is, furthermore, dependent on the lighting condition under which the film is visually examined.

The significance of this precept becomes more obvious when it is taken into consideration that a gray step wedge exposed in an intensity sensitometer should reproduce a wedge having all its steps neutral gray. The characteristic sensitometric curves of such a gray step wedge expressed in equivalent densities will by definition coincide (Fig. 1A). If, however, some of the steps are not neutral gray, the curves will no longer coincide; for example,

A contribution submitted March 22, 1950, by A. F. Thiels, Gevaert Photo-Products, Antwerp, Belgium.

*Designation of yellow by *j* follows the practice of Bingham[4] in which footnote 2 on p. 371 notes: The letters *J* and *j* are used instead of *Y* and *y* to represent densities in the yellow layer in order to avoid conflict with the notation of additive colorimetry.

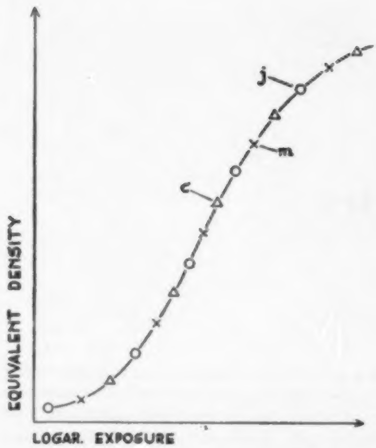

Fig. 1A. Characteristic sensitometric curves of a well-balanced color step wedge.

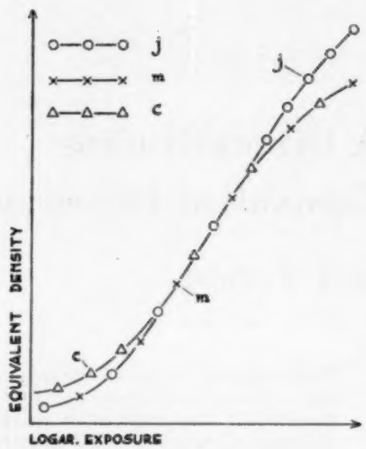

Fig. 1B. Characteristic sensitometric curves of an unbalanced color step wedge.

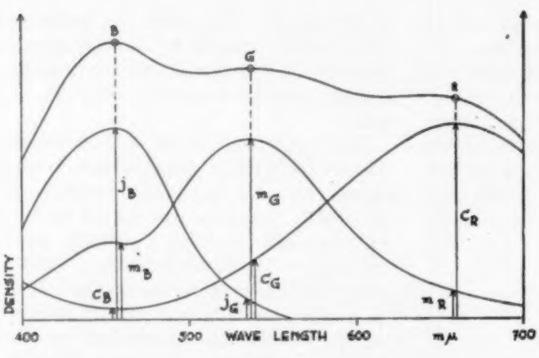

Fig. 2. Spectral diagram of a typical selection of primary colors.

when they have a touch of blue, the "yellow equivalent curve" will be lowest. The amount by which the color balance has been disturbed can be read directly from the curves.

For instance, on a step wedge of which sensitometric curves are as shown in Fig. 1B, the lowest densities have a bluish hue, the medium ones are neutral and the highest densities will have a brownish tint because of the predominance of yellow.

For the purpose of determining the characteristic curve of each layer, it is not possible to separate the different layers of the material and measurements must be carried out on the multilayer film as a whole. Different methods can be used in order to arrive at more or less accurate evaluations of the sensitometric curves of the individual layers: (a) by the conversion of measurements at three different wavelengths[3,4]; (b) by the recomposition of the color by means of three standardized primary color filters.[3,5]

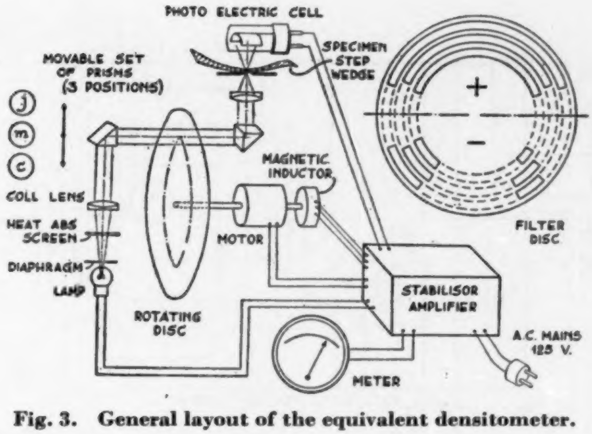

Fig. 3. General layout of the equivalent densitometer.

These methods are slow and, in addition to elaborate calculations, require specially trained personnel. Hence, methods had to be evolved by which direct determination could be obtained of sensitometric characteristics of the complete multilayer color film. Such a method is afforded by the equivalent densitometer.

The Equivalent Densitometer

To facilitate the understanding of its operation, a study of the spectral diagram of a subtractive color layer will be of great assistance. Figure 2 shows the spectral-density curves of a typical selection of primary colors and also the density curve of the composition formed by them. The information which is sought is the proportion of j_B of the yellow primary in the multilayer. Actually only the total density (through a narrow-cut blue filter) can be measured:

$$B = j_B + m_B + c_B$$

If it were possible to subtract automatically the proportions of the secondary absorptions, m_B and c_B, from the total measurement, the desired purpose would be attained.

Assuming a linear relationship between the secondary and the peak absorption of a primary color (which elementarily proves to be correct), thus, m_B/m_G = constant and c_B/c_R = constant with similar notations for other secondary absorptions, it may be inferred [see references 3 and 5] that the equivalent density, j, m and c of the three primaries, is found by the solution of the linear system of three equations:

$$\begin{aligned} j &= k_{11}B - k_{12}G - k_{13}R \\ m &= -k_{21}B + k_{22}G - k_{23}R \\ c &= -k_{31}B - k_{32}G + k_{33}R \end{aligned} \qquad \text{(I)}$$

B, G and R are total measurements through narrow-cut blue, green and red filters. The constants, $k_{11}, \ldots, k_{33}$, are positive numbers which are obtained from the absorption curves of the primary colors. The equivalent densitometer automatically solves this problem.

General Scheme

After passing through a heat-absorbing screen, the light of a stabilized underrated low-voltage lamp (Fig. 3) is collimated by a lens into a parallel beam which, by means of an adjustable set of totally reflecting prisms, is directed through one of the concentrically

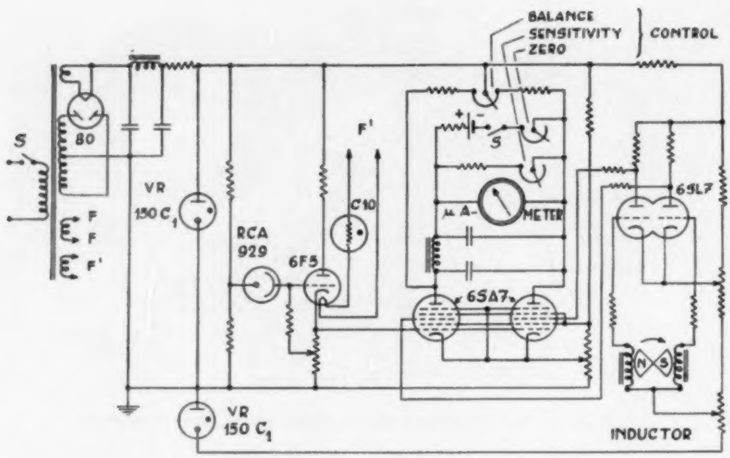

Fig. 4. Simplified layout of the electrical circuit of the equivalent densitometer.

arranged filter sets situated in a revolving disc. Through a second lens the rays are then converged and, after traversing a circular aperture and the sample strip to be measured, are directed onto the cathode of a photoelectric cell.

When the prisms are adjusted to direct the rays through the outer set of filters situated in the revolving disc, the equivalent density of the yellow primary can be measured in this position.

As the disc revolves at a constant speed of 2000 rpm, regular flashes of blue, green and red light strike the photoelectric cell and the currents generated in the latter are amplified and conducted to the measuring instrument. By means of the polarity reverser (magnetic inductor) which is mounted on the shaft of the rotating disc, the blue flashes are caused to pass through the d-c meter in a positive direction, the red and green flashes, respectively, in a negative direction. Furthermore, since the lengths of the filter bands are so balanced that after amplification the light impulses are proportional with the constants, k_{11}, k_{12} and k_{13} (shown in the first equation of the linear system I), it is possible to determine the quantity of j. Similarly, the other quantities, m and c, which are the equivalent densities of magenta and cyan, can be determined by adjusting the prisms to the corresponding filter segments of the rotating disc.

At the outset, the "density" of the selective filters was such that the combination of light source, filter and photoelectric cell statically gave identical readings for the three filters. Later it will be seen that, in order to make certain corrections, filter densities which are not always equal were adopted.

Basic Circuit

Figure 4 shows a simplified diagram of the amplifier circuit. The current generated in the photoelectric cell by light impulses is amplified in the first triode tube, of which the upper part of the tube characteristic is used to obtain an almost logarithmic amplification. The grid bias-resistance contributes toward

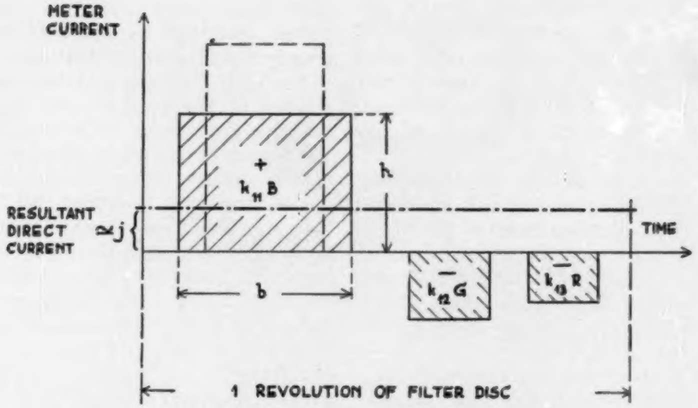

Fig. 5. Diagram of periodic impulses through the meter.

the achievement of this result.[6] The amplified signal is then transmitted to the parallel-coupled control grids of two heptodes. These act as a barrier and during one half revolution of the filter disc the left tube passes the signal, while during the other half revolution the right tube does likewise, in order that the direction of the current through the meter is alternatively reversed. This is attained by directing high square-wave voltages (±40 v) which vary in phase by 180 degrees, to the modulation grids of the heptodes.

The square-wave voltages are generated in the magnetic inductor which is synchronized with the revolving filter disc.* A π-filter only lets pass the resultant direct current thus protecting the meter against excessive alternating currents and eliminating vibration of the needle. The meter is a d-c 100-microammeter of which the scale, 125 mm in length, is calibrated in equivalent densities. The scale reads from 0 to 3. The shunt on the meter is so selected that a quick response of the needle is assured.

It is possible to make an electrical circuit by which a logarithmic amplification is obtained. Such an amplification gives a linear density scale over the whole measurable range.[6] Preference has been given to the adoption of a squared density scale. Although the intervals on this scale become somewhat short at the higher densities, they are nevertheless quite distinct and the accuracy in reading is not affected as is the case with logarithmic scales.

This amplification has the advantage that by an adequate choice of the selective filter densities certain apparent deviations of the Lambert-Beer law can be compensated, e.g., those caused by the curvature of the absorption curves of the selective filters, by fog other than that caused by dye components or by slight variations in the proportion of secondary and peak absorptions of the primary colors in function of density.

In fact, a closer observation of the impulse registration (Fig. 5) reveals, for

* The same result can be obtained by projecting light impulses of determined lengths synchronized with the revolving filter disc onto a set of photoelectric cells. Also, note the description of the improved electronic circuit given at the end of this paper.

example, that the impulse through the meter, $+ k_{11}B$ = surface $h \times b$, depends as much on the quantum of density (height h), which is the sum of the density of the (blue) selective filter and film density, as on the length of the filter (width b).

Changing the density of the filter and its length (while holding $k_{11}B$ constant) moves the operating range of the triode to a different portion of its nonlinear control characteristic. Thus different deviations from linearity could be obtained from the impulses provided by each filter.

For a linear relation between density and meter current, the filter density may be varied providing the length of the filter is properly adjusted so that the surface remains $b \times h = k_{11}B$.* This applies for whatever sample density is placed in front of the photoelectric cell. When the scale is not linear but, for example, squared, deviations will occur.

We shall not go further into these corrections now, but meanwhile it is clear that for constant-density disparities in the film strip, constant-current variations will show on the meter when the relationship is linear, and furthermore, that these constant-density disparities give no constant-current variations over several points of the meter scale, when the relationship ceases to be linear. These deviations allow compensation for the above-mentioned errors and they make the equivalent curves of the three primary colors coincide better.

Calibration of the Apparatus

The lengths of the filters in the circular slits of the disc are adjustable by means of sliding cover plates. The length of dark spaces between filters has no influence on the result because the "barrier tubes" do not allow current to pass when no light strikes the photoelectric cell. Therefore, the dark sections of the positive and the negative halves need not be equalized, which greatly simplifies the adjustment.

For each filter segment the relative lengths of the positive and negative selective filters have to be so adjusted that the apparatus will perceive only one of the primary colors. When, for example, the light traverses the outer filter segment of the disc which measures the yellow equivalent density of a film strip, the meter should respond to a density variation of the yellow primary, but not for density variations of the two other primary colors. By a careful selection of the filters and accurate adjustment of the filter lengths for any density of a primary color to be measured, needle deflections of less than 0.02 are obtained at any position on the scale for density variations of the other two primaries ranging from 0 to 3, no matter whether these densities are placed together or separately in front of the photocell.

After the ratios of lengths of the three filters have been established *within* each filter circle, these ratios must be preserved during an additional adjustment. This adjustment consists of proportional changes in the over-all lengths of the filters in the concentric circles, so that the meter deviations should be identical for the three positions of the reflecting prisms when measuring a visual neutral gray. This adjustment is necessary to make the densities of all three dyes register properly on a single meter scale. To this effect a series of visually neutral gray steps are carefully selected by a light of 3000 K.

The absolute length of the filters is finally established when the shunt rheostat, which is necessary to adjust the meter to zero, just critically damps the meter.

Lastly, the specular density of the neutral gray steps is determined with the aid of an optical densitometer (Martens' Polarisation Photometer) and on the basis of this measurement a scale

* (f.i. the broken-line rectangle)

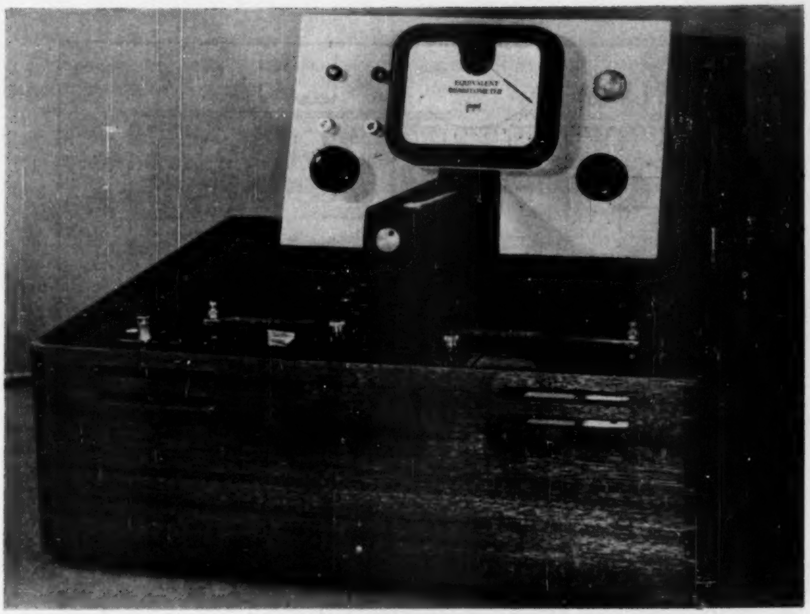

Fig. 6. Practical construction of the instrument.

is calibrated in specular equivalent densities.*

The adjustment of the apparatus is quite simple. The prisms are first aligned with the middle filter segment (measurement of the equivalent magenta). A calibrated filter of density = 3 is inserted in the head of the swivel measuring arm and placed in position in front of the photoelectric cell. By means of the regulator the needle of the meter is set on density 3 on the scale. The calibrating filter is then slid aside and the meter set to zero by a second control. The latter adjustment does not influence the former. The instrument is now ready for use.

The apparatus is fitted with a ratchet-slide which allows the wedge to be advanced layer by layer facing the aperture. This makes it possible to measure the color wedge layer by layer and overcomes the necessity of readjustment of the prisms for each step. The ratchet-slide assures that at every move exactly the same area of the wedge faces the aperture. For routine work the measuring arm can be fixed just above the test wedge.

The filter discs are made interchangeable so that the appropriate disc can be fitted for each set of primary colors. In theory it is possible to change the calibration of the apparatus electrically, but this implies the risk of errors and inaccuracies in the adjustment and therefore preference is given to the interchangeable discs.

The photograph (Fig. 6) shows the practical construction of the instrument.

Stability of the Apparatus

Special care had to be taken with the stability of the apparatus in view of the industrial line fluctuations.

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* In this respect, it is not essential that the optical system should fill the requirements of specular measurements.[7]

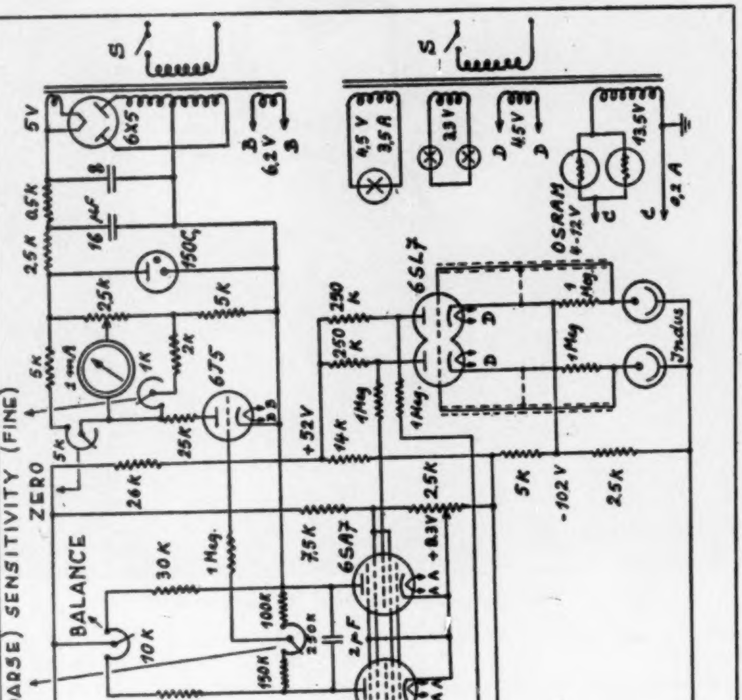
(COARSE) SENSITIVITY (FINE)
ZERO
BALANCE
6X5
RCA 929
6F5
6SA7
6F5
6SL7
OSRAM
+155V
−155V
+52V
−102V
150 C1
150C1
1 mA
Indus
4,5 V 3,5 A
4,5V
13,5V
0,2 A
6,3V
5V
6,2V

Figure 7.

With the apparatus under review, line voltage variations can be maintained within ± 1% by the introduction of a magnetic voltage stabilizer on the input line. The built-in voltage-regulator tubes and current regulators assure a stabilization of less than 0.1% for the crucial parts of the circuit. They completely check slow voltage changes over an interval of a few cycles. Short surges, if they occur at the moment when the photoelectric cell receives an impulse, are absorbed by the heavy choke which protects the meter. In order to increase the stability, the filament current of the first triode was reduced to 200 ma and stabilized with a ballast tube. In this way, no readable changes in full-scale deflections are noticeable with line voltage variations from 75 to 140 v (nominal voltage being 125 v). Table I shows a series of measurements of the magenta primary of a gray step wedge for voltages ranging from 135 to 75 v. No additional adjustments were made during the measuring.

Lacking a frequency generator, the systematic examination of the line frequencies is impossible. In practice, however, no effects of frequency variations of the line are experienced between 48.5 and 50.5 periods.

The consumption of the apparatus is 80 w and the warming-up time is about five minutes.

The instrument has been in use in our laboratories for about nine months and proved to be reliable. A standardized neutral wedge was measured every three or four days over a period of approximately two months. The maximum deviation recorded was 0.05, in the region of density = 2. This deviation was partly due to inaccurate positioning of the standard wedge in the ratchet-slide and may partly be attributed to the aging of the tubes and the photoelectric cell (variations in color sensitivity).

Acknowledgment

The author acknowledges the interest and advice of L. A. Meeussen, Gevaert Color-Film Dept., and F. T. Mees, radio-technician; and wishes to express appreciation to H. Verkinderen, Director of Research at the Gevaert Factories, Antwerp, for permission to publish this paper.

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Table I. Influence of Line Voltage Variations on the Measurement of the Magenta Primary Dye of a Gray Step Wedge.

Step No.:	1	3	5	7	9	11	13	15	17	19
135 v	.20	.31	.43	.67	1.00	1.30	1.57	1.86	2.22	2.53
125 v	.20	.31	.42	.67	.99	1.30	1.58	1.87	2.22	2.53
115 v	.20	.30	.41	.68	1.00	1.30	1.57	1.86	2.22	2.51
105 v	.20	.30	.42	.66	.99	1.29	1.55	1.85	2.22	2.51
95 v	.20	.31	.41	.67	1.00	1.30	1.56	1.87	2.22	2.52
85 v	.20	.31	.42	.66	1.00	1.31	1.57	1.87	2.23	2.53
75 v	.20	.31	.43	.68	1.00	1.31	1.57	1.86	2.23	2.53

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[*ADDENDUM:* Since this paper was submitted, the author has developed an improved circuit which is reported to have given entirely reliable service during the last half of 1950. The author has kindly supplied the diagram and brief description for inclusion at press time.—*Ed.*]

Improved Electronic Circuit

It is possible to use photoelectric cells to generate the synchronized square wave. As the construction with photoelectric cells, to replace the magnetic inductor, is of more universal practice, we here describe a complete circuit (Fig. 7) showing the disposition of the cells.

The use of photocells makes it possible, in addition, to take the length of the "positive filter" longer than 180° (e.g., "positive filter" 240°—"negative filter" 120°) so that the circumference may be more advantageously utilized.

The addition of an amplifier stage behind the barrier-lamps has the advantage that a more robust meter can be used (1- to 3-ma), whilst the amplifying characteristic of this stage can be so selected that a linear-density scale can be drawn on the dial.

A Versatile Densitometer for Color Films

By A. C. Lapsley and J. P. Weiss

A new densitometer for the analysis of color films reads densities with a narrow wavelength band at any desired wavelength between 350 and 760 mμ. This instrument was constructed utilizing two commercially available units: a Coleman Model 10-S Double Monochromator Spectrophotometer and a Western Electric RA-1100-B Densitometer. It has performed quite satisfactorily during more than two years of continuous service.

Research studies of color film required an instrument for measuring the spectral densities of dye images. For maximum utility, the instrument had to meet a number of specifications. First, density measurements were to be made with essentially monochromatic illumination. Second, provisions for measuring density at any wavelength were desired, because for research purposes density readings made at the wavelength of maximum absorption of a given dye were most useful. Another requirement was the ability to read to quite high densities, at least 4.0. This requirement was even more important for color densitometry than for black-and-white, since the spectral density of a dye may exceed appreciably the neutral density to which it contributes. Accuracy was another obvious requirement. To measure subtractive dyes accurately at high densities, only a very low percentage of stray white light could be tolerated in the monochromatic beam. Rapid and convenient operation was also specified. The instrument had to be operated by nontechnical personnel with sufficient rapidity to handle a large volume of color-film sensitometric strips. Reliable, trouble-free operation was also highly important.

Since none of the commercially available color-measuring instruments combined all the desired features, it was necessary to design one. In the interests of low design cost and maximum reliability an effort was made to utilize existing, proven components wherever possible.

Description

A special densitometer was constructed, incorporating a modified Coleman Model 10-S DM Spectrophotometer (made by American Instrument Co.) as the light-source unit and a Western Electric RA-1100-B Densitometer as the indicator. To obtain sufficient sensitivity to the radiant energy transmitted by the colored images, it was necessary to use a multiplier photo-

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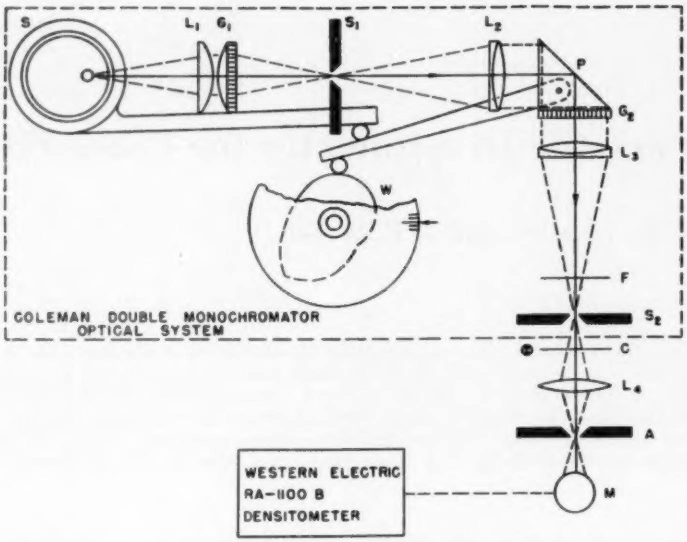

Fig. 1. Schematic layout of Color Densitometer.

Light originating at source S is resolved into monochromatic beam by the diffraction gratings, G_1 and G_2. Exit beam is focused by lens L_4 onto density located at A. Transmitted light is received by multiplier phototube M which is in turn electrically connected to the Western Electric Densitometer.

tube. Direct-current voltage for the phototube was provided by a rectifier and filter operating from the a-c lines.

The schematic diagram of the color densitometer appears as Fig. 1. The portion enclosed within the dotted lines is the original Coleman optical system. The light source, S, is a lamp with a vertical coiled, line filament which acts as the entrance slit of the monochromator. The first transmission grating, G_1, cemented to condenser lens L_1, forms its spectrum across a fixed slit, S_1, which passes a narrow spectral band into the second dispersing system. This light is collimated by lens L_2 and is reflected by a right-angle prism, P, through the second grating, G_2, and is focused on slit S_2 by lens L_3. The desired wavelength is selected by rotating the cam, W, which, linked by arms, swings source-slit S and rotates prism P so that the spectrum is swept across slit S_2, and the same wavelengths pass through both S_1 and S_2 at all times.

Added to the Coleman Spectrophotometer is a filter system, F, to reduce residual stray white light to a negligible amount. While the double grating monochromator passes only a small amount of stray white light, stated as being a fraction of a per cent, the requirement of light purity is very stringent if dye densities up to 4.0 (a transmittance of 0.01%) are to be read. The subtractive dyes used in color photography have fairly narrow absorption bands, roughly one-third the visible spectrum, and they transmit the other two-thirds of the spectrum quite freely. To minimize errors from this cause, the appropriate one of five fairly narrow band-pass filters may be put into the light beam. The transmittance of these

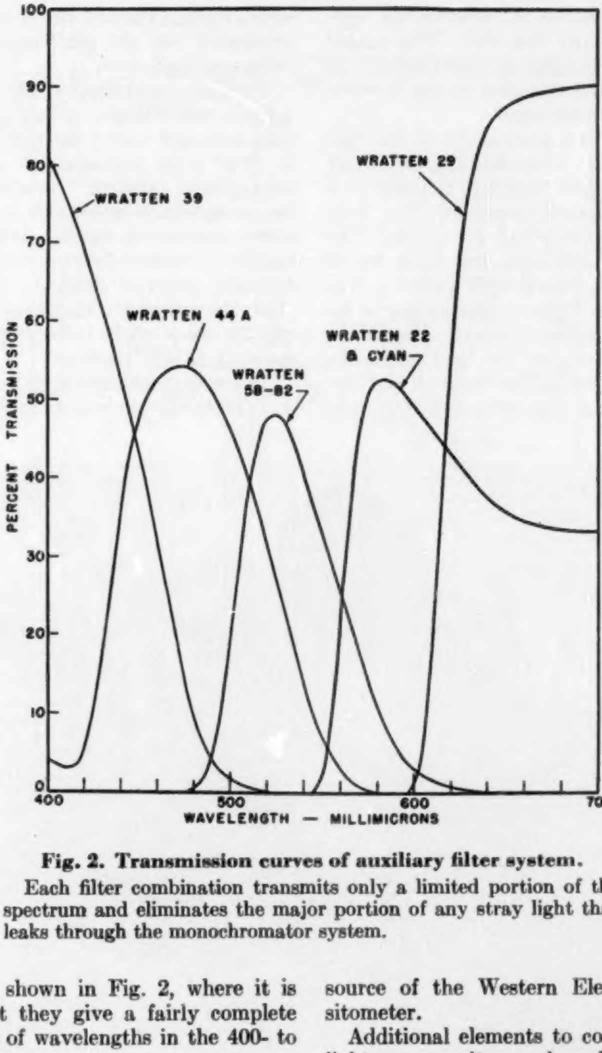

Fig. 2. Transmission curves of auxiliary filter system.
Each filter combination transmits only a limited portion of the spectrum and eliminates the major portion of any stray light that leaks through the monochromator system.

filters is shown in Fig. 2, where it is seen that they give a fairly complete coverage of wavelengths in the 400- to 700-mμ range.

To provide a pulsating signal to the Western Electric amplifier, which is tuned to a frequency of 450 cycles/sec, the light is interrupted by a chopper, C. This consists of a 15-slot disc driven by an 1800-rpm synchronous motor, just as in the original light source of the Western Electric Densitometer.

Additional elements to complete the light-source unit are a lens, L_4, to focus an image of exit slit, S_2, at the film aperture, A, and two mirrors which cause the final image to be oriented properly. The film aperture and the sensitometric strip-holder are identical with those on the Western Electric instrument. The multiplier phototube, M, mounted be-

low the aperture, A, receives the light transmitted by the film. The output of the phototube is electrically connected to the amplifier of the Western Electric Densitometer.

Figure 3 is a photograph of the light source unit with housing removed. The L-shaped casting contains the Coleman optical elements. The light source is at the left of the casting. The knob and dial near the light source comprise the wavelength control. The knob at the right of the casting is for the filter system. Clearly seen is the slotted interrupter disc and its motor. The black housing in front of the disc contains the lens and mirror system which focuses the exit slit of the monochromator on the photographic film being analyzed.

The light transmitted by the film sample falls on the multiplier phototube mounted below the film aperture. A 1P22 tube was selected as having appropriate spectral sensitivity. It has considerable sensitivity at 700 mμ, where response is wanted, but falls off rapidly in sensitivity at about 750 mμ. Infrared response must be kept low since the infrared transmission of most organic dyes might otherwise lead to spurious density readings.

The wiring diagram is shown in Fig. 4. Direct-current voltage for the multi-

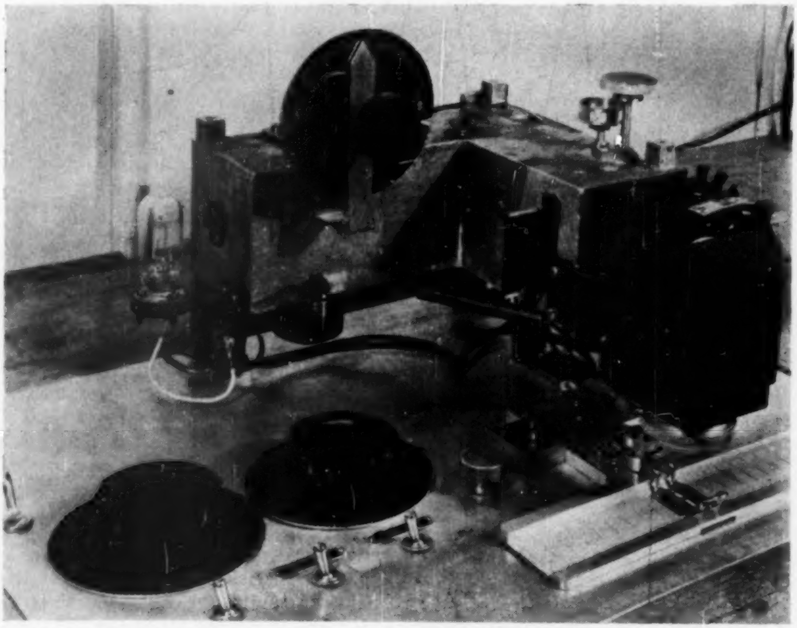

Fig. 3. View of light-source unit with housing removed.

Large casting to the rear contains Coleman double monochromator optics. The motor-slotted disc combination at the exit of the housing serves as a light interrupter which allows an a-c electrical signal to be picked up from the phototube. Housing on the near side of the motor contains a mirror-lens system for focusing and orienting the light from the exit slit onto the density to be analyzed.

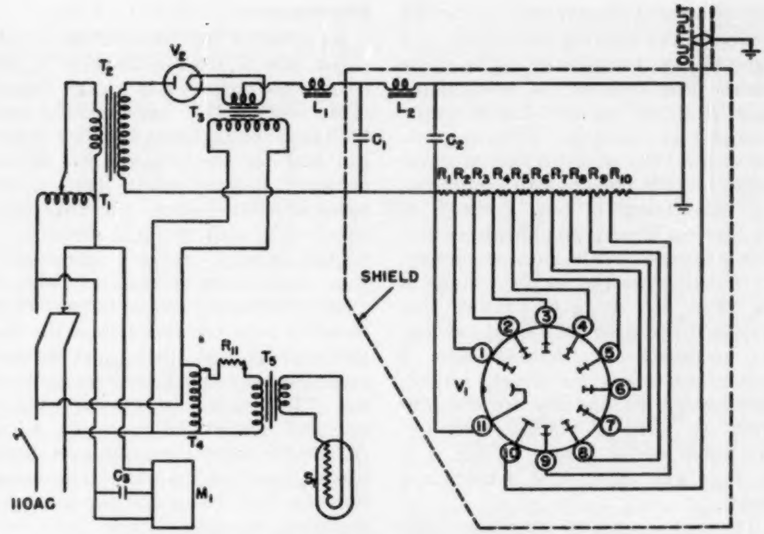

Fig. 4. Wiring diagram of the Color Densitometer.
High voltage supply to the multiplier phototube, V_1, and low voltage supply to the light interrupter motor, M_1, and light source, S_1, are shown.

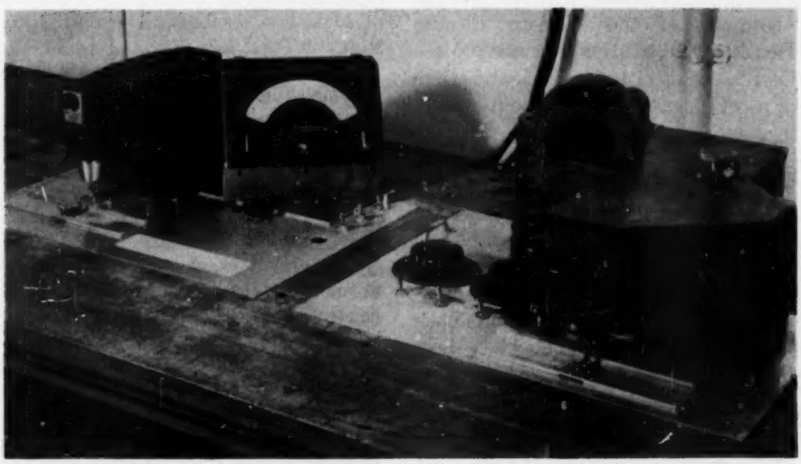

Fig. 5. The mounting of Color and Western Electric Densitometers.
The meter on the Western Electric unit has been rotated to face the Color Densitometer operator.

plier phototube dynodes is provided by rectifying and filtering the output of a high-voltage transformer. The two-section filter reduces the residual a-c signal to a level too low to cause errors, even at high densities. Since the output of the 1P22 as a function of wavelength is quite nonuniform, a gain control independent of that available in the Western Electric amplifier is needed. This is supplied by the autotransformer, T_1, which varies the supply voltage to the 1P22. By doing this rather than varying the intensity of the light source, the maximum signal-to-noise ratio is maintained at any wavelength setting. Line-voltage fluctuations are compensated by using a voltage stabilizer. The other wiring shown in Fig. 4 is for the light source and synchronous motor.

The signal output from the 1P22 phototube is fed directly to the first amplification stage of the Western Electric RA-1100-B Densitometer,* an instrument very well known in the motion picture industry. The connection is made, through a shielded coaxial cable, in parallel with the No. 929 phototube of the Western Electric Densitometer; this allows use of the instrument as either a black-and-white or a color densitometer without switching.

The complete color densitometer assembly is shown in Fig. 5. The monochromatic light source is to the right and the Western Electric Densitometer to the left. It may be noted that the density meter of the latter has been rotated to face the operator of the color densitometer. The meter has been mounted on a column and may be swung to face an operator of either instrument.

*J. G. Frayne and G. R. Crane, "A precision integrating sphere densitometer," *Jour. SMPE*, vol. 35, pp. 184–200, Aug. 1940.

Performance

As noted in the introduction of this paper, one of the requirements of the color densitometer was a high degree of accuracy. This has been checked, both for phototube and amplifier linearity, and for the presence of minute amounts of stray white light in the monochromatic beam. Linearity tests were made with specially constructed neutral density "filters." These were thin brass discs perforated with a series of uniformly spaced holes. Their densities were calculated from the size and spacing of the holes and checked experimentally on an accurate photometer. Two such discs, having densities of 0.495 and 1.015, were on hand. At various selected wavelengths, these filters were individually introduced into the light beam and the indicated densities recorded. Then with the filters removed, the light intensity was reduced until the meter indicated the value recorded for the 1.015 filter. At this light level the two discs were again introduced into the beam and the densities recorded. This process was repeated until an indicated top density of 4.060 was reached. The results are shown in Table I.

Up to the top density of 4.00 it is seen that there is good linearity at wavelengths throughout the visible spectrum. The shouldering that appears at 350 and 760 mμ at high densities is probably the result of phototube noise caused by the high voltage that has to be applied to it at these wavelengths.

The above checks, however, would not indicate the presence of stray white light. This can be serious, for if there is 0.01% unwanted light which is not absorbed by the selective dye, it will cause a density error of 0.002 at a density level of 2.0, 0.02 at a level of 3.0, 0.12 at 3.5 and 0.32 at 4.0. This rapid increase of the error at high densities suggests a ready method of checking. This is to measure the density of two selective absorbers at the level of 2.0

Table I. Densities measured at various wavelengths.

True Density	Wavelengths, mμ 350	440	540	700	760
0.495	0.51	0.50	0.495	0.50	0.505
1.015	1.03	1.02	1.025	1.02	1.035
1.510	1.51	1.52	1.52	1.52	1.54
2.030	2.05	2.04	2.04	2.04	2.06
2.525	2.54	2.51	2.54	2.54	2.55
3.045	3.03	3.06	3.065	3.06	3.05
3.540	3.40	3.55	3.55	3.57	3.42
4.060		4.02	4.04	4.01	

Table II. Density checking results.

Wavelength, mμ	Strip 1	Strip 2	Strips 1 & 2 Calc.	Read
600	1.30	1.18	2.48	2.49
610	1.33	1.21	2.54	2.54
620	1.39	1.27	2.66	2.66
630	1.52	1.37	2.89	2.90
640	1.61	1.44	3.05	3.03
650	1.68	1.51	3.19	3.18
660	1.78	1.58	3.36	3.34
670	1.82	1.63	3.45	3.44
680	1.87	1.66	3.53	3.52
690	1.88	1.67	3.55	3.56
700	1.86	1.65	3.51	3.50

and to measure the density of their combination. Such a test has been carried out on a sample of color film in the wavelength region 600–700 mμ, with the results tabulated in Table II. It is seen that there is no noticeable error caused by stray light.

The color densitometer has given quite trouble-free performance. It has been in daily use for over two years. The only attention required has been occasional replacement of the lamp.

Discussion

M. C. Townsley: Is the receiver which receives the energy after it passes through the film so arranged that it reads diffuse density or is it substantially specular density?

Mr. Lapsley: Actually, it probably reads a combination, but closer to specular density. That is, we don't have any integrating sphere. We use light which is focused onto film and which diverges beyond the film. The phototube is mounted close enough that it catches all of the light that passes through the film, or at least a major portion of it. This instrument as we built it was designed primarily for color-film work, using dyes which have only a negligible amount of scattering, and it is our opinion, which has been checked up to the limits that we can check, that the density it measures would actually be the specular and diffuse density.

Mr. Townsley: Do you feel that, for a dye material, the specular density and diffuse density are not very different?

Mr. Lapsley: That is correct. We of course could not make measurements on black-and-white film with that instrument, but there would be no point in doing so.

Anonymous: Have you found any difficulty with selective fatiguing of the multiplier phototubes?

Mr. Lapsley: We have not found any difficulty with that as such. Maintenance of a constant relationship of output versus wavelength is not required for proper operation of this instrument. Zero adjustment is convenient and is made for the wavelength selected just before density measurements are made.

Recent Studies on Standardizing the Dubray-Howell Perforation for Universal Application

By W. F. Kelley and W. V. Wolfe

The adoption of safety base film throughout the motion picture industry has required the abandonment of the Bell & Howell perforation for color release prints. This fact presents an opportunity to achieve the long-desired goal of a single standard perforation for negative and positive films in all applications. Tests are described and conclusions reached covering registration problems in the studio, studio laboratory and release laboratory, as well as accelerated and normal release life tests on Dubray-Howell perforated black-and-white prints.

The importance of the perforations on the side of a motion picture film would be difficult to overstate. Those perforations are relied upon for propulsion and registration in every photographic and projection operation in the making and exhibiting of a motion picture. Unfortunately, the importance of these perforations is not understood by a great many people in the industry, and even those who do realize their importance are often inclined toward the philosophy that "what was good enough for my father is good enough for me."

The history of the perforation size and shape is contained in the Journals of this Society and that information was very excellently gathered and presented by the Film Dimensions Committee in the April, 1949, Journal, at which time it was proposed, for the third time, that the Dubray-Howell perforation should be adopted as a universal standard.

Just to review this situation briefly, note that the first accepted standard perforation was the familiar Bell & Howell perforation which, prior to 1923, was standard throughout the industry for both negative and positive use. Because of nonstandard projector sprockets, the inherently weak tear-resistance of the Bell & Howell sprocket was aggravated. A number of the pioneer engineers of the industry and of this Society considered the problem and came up with the present Eastman positive perforation which was accepted throughout the industry for release print purposes. Even at that time, however, there were many voices raised in opposition to a different standard perforation for negative and positive applications.

In 1932 Messrs. Dubray and Howell proposed a perforation combining the

Presented on October 19, 1950, at the Society's Convention at Lake Placid, N.Y., by W. F. Kelley and W. V. Wolfe, Motion Picture Research Council, Inc., 1421 N. Western Ave., Hollywood 27, Calif.

rectangular shape of the positive perforation with the 0.073-in. height of the negative perforation, thus obtaining the best features of both perforations from the standpoint of existing equipment, registration and projection life. Nevertheless, in 1933 this Society adopted the Eastman positive perforation as the universal standard for both negative and positive film. However, the industry refused to accept this universal standard because it required changing every camera, projector or printer throughout the world.

In 1937 the Subcommittee on Film Perforation Standards recommended that the 1933 standard be withdrawn and again proposed the Dubray-Howell perforation as the universal standard. This report was turned down by the Standards Committee because it was felt at that time that the large amount of background film accumulated in the libraries would prevent the universal perforation from being used.

Beginning in 1947 and continuing since that time, your Film Dimensions Committee, under the chairmanship of Dr. E. K. Carver, has continuously had on its agenda the problem of securing a universal standard perforation acceptable to all of the industry. Tests made by many people predominently supported the early contention of Dubray and Howell that this rectangular perforation with an 0.073-in. height was satisfactory for all negative and positive purposes. M. G. Townsley at Bell & Howell demonstrated in some tests made not long ago that Dubray-Howell perforated film would operate with satisfactory steadiness in a camera equipped with a Bell & Howell full-fitting pilot pin.

This situation might have continued without any conclusion for a long time but for the introduction by Eastman Kodak Co. of the new safety base film. Prior to this time, all of the commercially used color systems employed Bell & Howell perforated release prints because of the need for a high degree of registration in making such prints; but, because the new film base is reported to be somewhat lower in its tear strength than the nitrate film base, two color systems adopted the Dubray-Howell perforation and are currently using it. Both Trucolor and Cinecolor in making this decision found that they could successfully register from Bell & Howell perforated negatives to Dubray-Howell perforated color prints.

Technicolor, unfortunately, although fully aware of the industry's long struggle for a universal perforation and of the successful use of the Dubray-Howell perforation by other color companies, adopted the Eastman positive perforation without consulting or advising the producing companies of that decision. Perhaps Technicolor did not realize the studio significance of this decision. However, when studio photographic effects departments were notified that after a certain time all Technicolor prints would be supplied with Eastman positive perforations, it became immediately evident that process projectors and perhaps other studio-owned precision equipment would require interchangeable movements in order to handle both Technicolor prints and black-and-white, or prints of any other color system. The cost of duplicating such movements is in itself moderately high, but what is much more important, such a situation materially adds to the danger of confusion and delay in any operation involving process projection photography.

The matter was called to the attention of the Research Council and a meeting involving all those interested, from manufacturers, commercial laboratories and studios, was held. As a result of this meeting, a comprehensive series of tests was laid out by the Research Council in the hope that the industry could be convinced that this was the time to adopt a universal standard perforation and thus for all time avoid any further confusion and expense which must in-

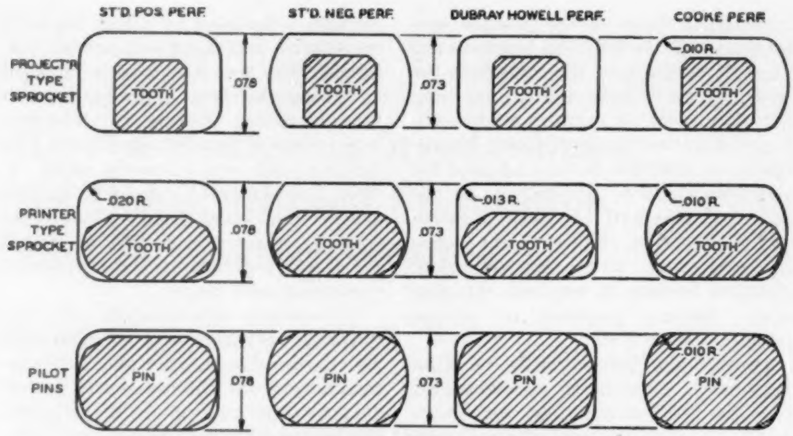

Fig. 1. Drawing showing the fit of various perforations, pilot pins and sprocket teeth.

evitably result from what used to be a double standard and is now a triple standard.

Four perforations were considered: the Bell & Howell, Eastman positive, Dubray-Howell and Cooke (Fig. 1). Experience and history had already eliminated the Bell & Howell and the Eastman positive perforation as candidates. Discussion with experts in printing problems, particularly having to do with the continuous type of printer on which better than 90% of all release prints are made, revealed that the square end of the Dubray-Howell perforation was preferred over the rounded end of the Cooke perforation. It was also the belief of many industry experts that in other problems of registration, the Dubray-Howell perforation was superior to the Cooke. As a result, efforts were confined entirely to the Dubray-Howell perforation.

Generally speaking, there are two problems involved: one is projection life and the other is registration. Each, of course, has a variety of important problems under that general heading. Study of projection life was divided into two parts: accelerated tests and normal release tests. Actually, there is already considerable experience in normal release through the color systems which are using the Dubray-Howell perforation commercially, but it was recognized that these color prints present a different projection-life problem than normal black-and-white prints. Accelerated life tests on black-and-white prints, made by other investigators on carefully aligned projection equipment, have shown approximately 10% greater life with the Eastman positive perforation than that obtained with the Dubray-Howell perforation. It was, however, recognized by the engineers in charge of these tests that normal release conditions might indicate a different answer because theater projectors are not universally as well aligned as these test projectors. Accordingly, the accelerated test was deliberately made in a projector out of alignment and using badly worn sprockets. Figure 2 is a photomicrograph of one of these sprocket teeth. Since it is badly undercut on both sides of the tooth, it has probably been reversed in the machine at some time during its life. This test reel was run approximately 300 times before the

test was stopped. Although the film was not run to destruction, it was evident at this time that in a machine as badly aligned as this one, the film could not run many more times.

Figure 3 shows a photomicrograph of one corner of the Eastman positive perforation at the end of the running, and Fig. 4 shows a similar corner of a Dubray-Howell perforation. In both cases the tooth interfered at the corner of the perforation and caused a serious rupture of the film. Inspection of about 80 ft of each of the two prints involved in the reel led to the conclusion that the Dubray-Howell perforation was standing up a little bit better under this particular test than the Eastman positive perforation. While this is contrary to the projection-life tests previously referred to, it is not an unexpected difference, because the smaller radius of the corner fillet in the Dubray-Howell perforation means that the straight portion of the perforation is longer than is the case in the Eastman positive perforation; thus, corner interference will begin with an Eastman perforation before it begins with a Dubray-Howell perforation.

As this article is being written, the partial release test has not yet been completed, but there is a picture in release in the Los Angeles exchange area in which half of the 1000-ft release is perforated with the Eastman positive hole, and the other half uses the Dubray-Howell perforation. These are so staggered as to fairly cover head reels and tail reels and both projectors in any theater where the print is run. No diffi-

Fig. 2. Photomicrograph of a sprocket tooth of test projector.

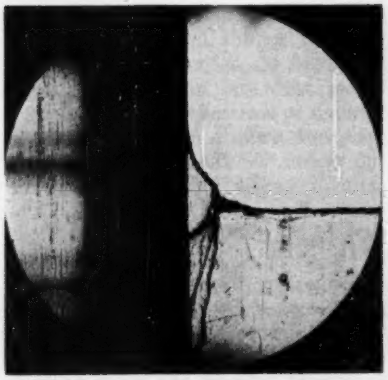

Fig. 3. Photomicrograph of the corner of an Eastman positive perforation.

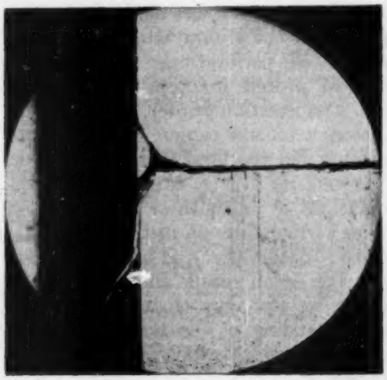

Fig. 4. Photomicrograph of a corner of a Dubray-Howell perforation.

culty is foreseen in this test; in fact, it is expected that it, too, will support the results that have been obtained experimentally and commercially in so many other cases.

The registration tests required a great deal of careful planning and became involved in factors which are not in themselves a part of the test. Since the industry is in the process of changing from nitrate base negatives to safety base negatives, factors which might be influenced by this change in base material could not be neglected. Similarly, the low shrinkage characteristics of the safety base film have made it necessary to manufacture such negatives with a shorter than standard perforation pitch. Thus the perforation pitch had also to be considered in this test.

In projection process photography, stationary foreground objects are commonly photographed together with the rephotographing of a projected picture. This, in the final composite result, provides an extremely critical test of the steadiness of a motion picture, since the eye constantly has the opportunity to observe foreground and background objects where any relative motion is exaggerated. Since this form of photography presents one of the most critical registration problems in the industry, it was chosen as the test method for comparison of the Dubray-Howell and Bell & Howell perforations. Briefly, the over-all process involves the first camera, a registration printer, a process projector, a second camera, a continuous printer and the final theater projector. The outline in Fig. 5 shows the combinations of all of these factors which were carried through in this test. The basic situation involved is quite simple, but the detail results in complications which require very close study for an understanding of the tests themselves and the results which have been obtained.

The program was laid out to cover all practical combinations of pilot pins and perforations for nitrate and safety base, short pitch and standard pitch negatives, in a chain of operations which was as follows: A chart, as shown in Fig. 6, was photographed in the background camera. The film was rewound, the chart shifted slightly and a second exposure was made. This film was developed and printed in a step contact printer, resulting in a process plate as shown in Fig. 7. This process plate was then projected through a process projector onto a translucent screen. Between the process projector and the screen was a latticework covering the full area of the screen. This casts a network of black lines on the screen itself and provides a new reference point. A standard production-type camera photographed this process screen and normal release type prints were made from that negative.

Figure 8 shows a frame of the release print. The parallel white lines and the identifying slates at the top middle and lower right were photographed by the first camera and projected on the process screen. The network of black lines is the shadow of the latticework between the projector and the screen, the broad black line extending in an "L" shape at the lower right corner was created by a gobo [section of dark wallboard often set up to shield camera lens from light] placed in front of the screen. Similarly, the broad black line at the lower left corner with the narrow white stripe through it vertically was created by a gobo with a slit in it located in front of the screen, so that the light coming through the slit from the process screen caused the vertical white line. The slate in the lower center marked "Reel b," was located in front of the screen. In projecting these prints, the salient points looked for were movement between the white lines, which is a function of the background or first camera, movement between the black network lines and the white chart lines, which is a function of the first camera, the

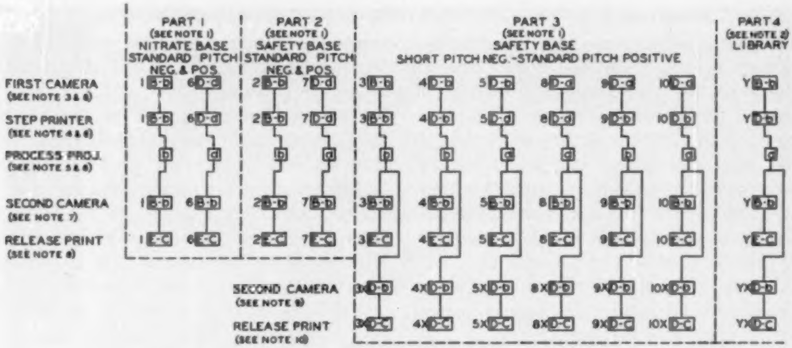

Fig. 5. Outline of perforation registration tests.

Legend:

Numerals – Test number.

Capital Letters – Type of perforation.

Small Letters – Type of registration pin.

B – Bell & Howell (negative) perforation.

D – Dubray-Howell perforation.

E – Eastman (positive) perforation.

b – Bell & Howell registration pin.

d – Dubray-Howell registration pin.

C – Continuous printer.

Note 1: These titles describe the film used in the first (background) camera and process (background) projector only, and do not refer to the second camera negative or the release print.

Note 2: This is the only case where the background negative and positive were of different base material. This background negative was nitrate base, Bell perforated, exposed on a Bell & Howell pin. The background print was Dubray perforated, standard pitch, safety base, made on a step printer having a full fitting Bell & Howell pin, and projected on a background projector having a full fitting Dubray-Howell pin. This would be the procedure followed on existing library material if the Dubray-Howell perforation were adopted as a universal standard.

Note 3: Two full-aperture first (background) cameras were used; the one, in line with regular procedure, had a full fitting Bell & Howell registration pin; the other camera had a full fitting Dubray-Howell registration pin.

Note 4: Two step printers were used; the first had a full fitting Bell & Howell registration pin; the second had a full fitting Dubray-Howell registration pin.

Note 5: Two background process projector movements were used; the first had a full fitting Bell & Howell registration pin; the second a full fitting Dubray-Howell registration pin.

Note 6: The small registration pin (full fitting in height only) was not changed in any of the equipment mentioned in Notes 3, 4 and 5. This is a satisfactory procedure, as the Bell & Howell and the Dubray-Howell perforations are identical in height dimensions.

Note 7: The second (rephotographing) camera had a Bell & Howell registration pin. In this particular series, the negative was Bell & Howell perforated, standard pitch, nitrate base.

Note 8: All these release prints were made on a continuous printer, using an Eastman perforated, standard pitch, safety release positive.

Note 9: This second (rephotographing) camera was identical to the camera described in Note 7, but the negative was Dubray perforated, short pitch, safety base.

Note 10: These release prints were made on the same continuous printer described in Note 8, but using Dubray perforated, standard pitch, safety release positive.

printer, or the process projector, and movement between the production camera aperture and the black gobo in the lower right corner, which is a function of the production camera. Movement of the release printer is shown by the relationship between the sprocket holes and the production camera aperture line and, of course, movement in the final projector is shown by a movement of the sprocket holes themselves.

No attempt has been made in this discussion to enter into the fine details of identifying and measuring the several possible sources of instability, but sufficient information is provided so that by careful study an understanding of the possibilities of analyzing this chart can be obtained. It should perhaps be sufficient to say that by means of these special charts, gobos, latticeworks, special printer and camera apertures and such other devices, the source of any movement which takes place in this chart as it is projected on the screen can be isolated and identified. This was, of course, a fundamental necessity in a test program containing the detail involved in this one.

Several practical problems face the industry if the Dubray-Howell perforation is established as the universal standard; they are: projection life, the use of library negatives with Bell & Howell perforations, the use of Dubray-Howell perforated negatives in cameras with Bell & Howell pilot pins and, of course, the over-all optimum registration obtainable with Dubray-Howell perforations throughout each step in the production of a motion picture.

On the basis of these tests, the following predictions and conclusions are made: There will be no commercial loss in projection life of Dubray-Howell perforated prints as compared to Eastman perforated prints; library negatives with Bell & Howell perforations can be printed to Dubray-Howell perforated process plates with satisfactory

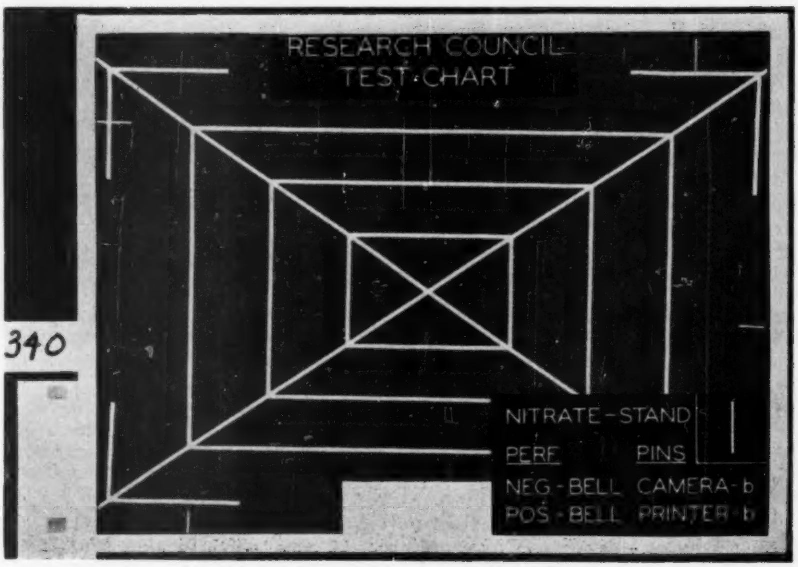

Fig. 6. Original chart — registration tests.

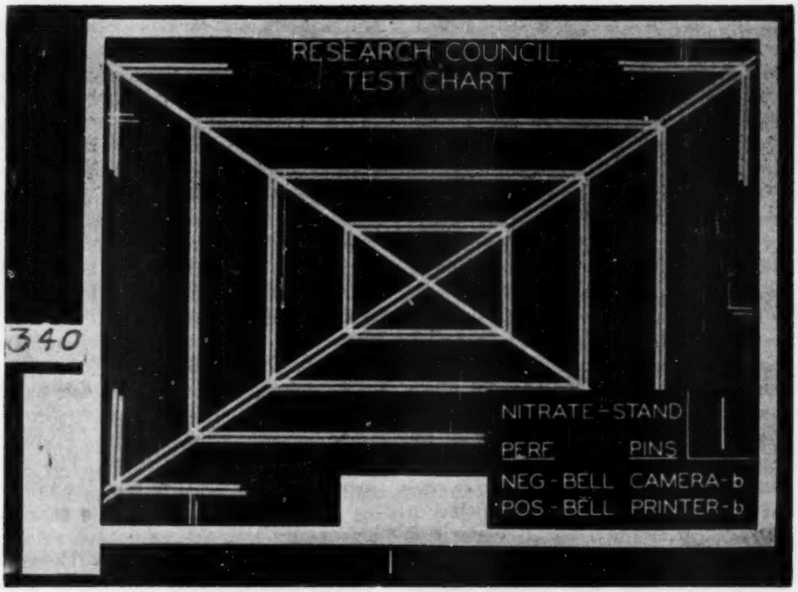

Fig. 7. Process plate — registration tests.

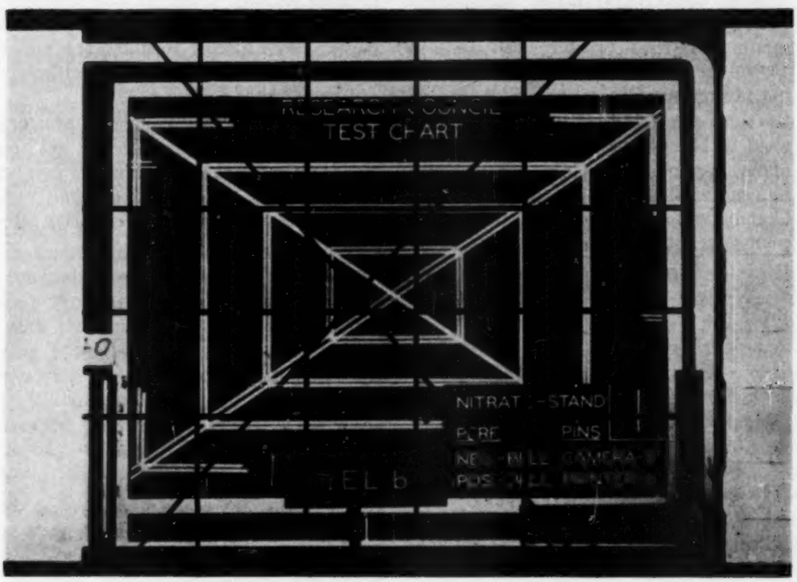

Fig. 8. Release print — registration tests.

results, except where the most critical registration problems are involved; Dubray-Howell perforated negatives can be used in existing cameras without change, and release printers do not need to be changed for printing Dubray-Howell perforated negative or positive films, although some additional improvement can be obtained if the sprockets in such continuous printers are changed to take full advantage of the Dubray-Howell perforation.

The Research Council expects to recommend to its Board of Directors that the Dubray-Howell perforation should be presented to the American Standards Association for adoption as the universal standard perforation for negative and positive motion picture film. Furthermore, it expects to recommend to its member companies that in the use of Dubray-Howell perforated negative and print stocks for normal studio operations, they should change pilot pins in cameras used primarily for process background films, registration printers and process projector movements; a step printer with Bell & Howell pins should be retained for printing library negatives; the pilot pins in the normal production cameras will not need to be changed except as a matter of maintenance; and release printers may be used without change. The Research Council will also recommend changes in pilot pins and sprockets for new cameras and printers, and for replacement parts.

In support of these test results, there is not only the very considerable amount of experimental work done by others throughout the last twenty years, but currently there is considerable commercial experience. Mention has already been made of Trucolor and Cinecolor, both of whom are using Dubray-Howell perforated release prints; but in addition to these it should be noted that Eastman color positive, Du Pont color positive and one experimental negative, as well as its companion positive, are all using Dubray-Howell perforations.

To summarize briefly, the tests made by the Research Council have confirmed and extended the data obtained by other experimenters in this field. The Research Council believes that the industry has an opportunity at this time to achieve the long-desired goal of a single standard perforation. If the Dubray-Howell perforation is adopted as that universal standard, no confusion will be created at any point in the industry, nor will it be necessary to expend any considerable money to make the minor conversions which are desirable although not completely necessary.

It is strongly recommended that every effort be made at this time to get the complete support of the industry behind standardizing the Dubray-Howell perforation for all negative and positive purposes.

Effects of Television on the Motion Picture Theater

By Benjamin Schlanger and William A. Hoffberg

The advent of television has accelerated the need for refinements and improvements in the art of the projected motion picture in theaters. The factors of cinematography, theater location, seating capacity and theater design have to be dealt with in accordance with circumstances which already appear to call for a fresh approach to the problem. It is important to evaluate the ability to adapt existing theaters to the new requirements.

Although home television seems to be acquiring a mass audience, there will always be a motion picture theater and theater television audience consisting of those patrons who wish to see entertainment not available in other mediums, those who wish to avoid advertising intrusions, those desiring a respite from the home environment, those satisfying their gregarious instincts and those who prefer the dramatic impact of the large theater screen cinematography. This audience may be surprising in numbers because it has been estimated that only 10 to 20% of the potential audience ever attended even the most popular picture.

We are now going out of a period in motion picture history in which great leeway existed in both production and exhibition. The margin for error, incompetence and acceptability of questionable quality of production and exhibition is narrowing down with the advent of television. Now, the factor of quality in motion picture theater entertainment will determine the size of its audience. Of course, quality primarily includes story content and performance, but if the motion picture theater cannot deliver the story content and performance in a manner far superior to any of the other entertainment mediums, it will lose the main reason for its existence.

Television has accentuated the necessity for intimacy in the motion picture theater because each home television seat is a "ringside" seat. The television camera is located at a distance and angle from the scene which the director considers most favorable to the home audience. At home, the television viewer has the great advantage of choosing his seating pattern by individual preference. However, the scale of the television screen in the home is limited.

Presented on October 20, 1950, at the Society's Convention at Lake Placid, N.Y., by Benjamin Schlanger and William A. Hoffberg, Theater Engineering and Architecture Consultants, 35 W. 53d St., New York 19.

The comparatively bright illumination levels required in home television viewing makes the viewer particularly conscious of this deficiency. The inclusion of furniture and room details in the field of view does much to destroy intimacy.

In contrast with home television, the motion picture theater has a fixed seating pattern. The theater audience seating preferences can readily be seen as they choose their seats at the beginning of the show. The less desirable seats are then reserved for latecomers.

Improving Theaters

The competition of home television can be a healthy stimulus to induce theater owners to improve their physical plant so that the enjoyment of a motion picture in a theater is noticeably superior. The following items deserve careful consideration in this connection:

1. All theater seat locations must be desirable. Unobstructed vision of the screen is mandatory. Ample row spacing and two arm rests for each seat will be necessary.

2. The scale of the theater screen image should increase so that the difference in scale as compared with the home television screen is accentuated and dramatized.

3. Since 1938, we have advocated the elimination of black masking around the motion picture screen and we now have many successful installations of this type in theaters. The majority of television receiver sets have very light colored maskings. A luminous field around the screen, preferably synchronized with the screen lighting intensities, would reduce eyestrain and enhance peripheral cinematographical effects.

4. Some of the fluidity and inventiveness achieved in television production is worth noting. With the larger screen and luminous screen surround, the peripheral areas of the human field of view can be exploited for greater dramatic effect.

5. The effectiveness of distant panoramic views and medium shots on the television receiver is necessarily limited in scale. In contrast, the larger theater screen and the increased use and improvement of wide-angle camera lenses, are great advantages.

6. Development of higher intensity projection equipment, coated lenses, and the reduction of film grain as well as the demands of drive-in projection, have made larger screen projection feasible.

7. Further enhancement of cinematography is produced by the increased subtended angle of the larger screen to the average viewer.

8. Items 2 and 3 of the above recommendations can now help to bring three-dimensional motion pictures into use. With seating depth limited to approximately four times the picture width instead of the greater viewing depths now used, objectionable perspective distortions experienced in stereoscopic viewing will be reduced. The elimination of dark picture surrounds is highly consistent with the realistic effect of stereoscopic viewing.

9. Stereophonic sound in theaters giving positional sound effects in space can hardly be conceivable in home television sound.

The above suggestions for improvement must, of course, be adaptable to existing theaters. In a survey of about 600 U.S. theaters, which was conducted by this Society in 1938, an average screen width of 18 ft 6 in. and an average ratio of maximum viewing distance to picture width of 5.2 was found. An increase of average screen width to 24 ft 0 in. would reduce the ratio of maximum viewing distance to picture width from 5.2 to 4.0 and would increase the screen area by about 67%. This change would be structurally feasible in the majority of existing theaters. It is true that in many of the existing theaters, the use of several of the front rows would be eliminated but the seat loss would be nominal.

With reference to the elimination of black screen masking, the observations and conclusions of L. A. Jones, S. K. Wolf, F. M. Falge, W. D. Riddle, B. O'Brien, C. M. Tuttle, R. G. Williams, H. L. Hogan, M. Luckiesh, and B. Schlanger, since 1920, have indicated the desirability of illumination of screen surroundings. The most desirable contiguous brightness has been found in practice to be the synchronous type which automatically varies with the brightness of the picture. Some of the many examples of this type are the Island Theater, Bermuda; Crown Theater, New Haven; Essoldo Theater, Penge, England; and the Tacna Theater, Lima, Peru. Further developments and refinements for providing a synchronous luminous screen surround have been incorporated into several theaters now under construction, including the Shopping Center Theater in Framingham, Mass., and the Bellmore Theater, Bellmore, L.I.

Locating Theaters

New motion picture theater construction in the U.S. has not been proportional with the increase of population. The growth of television is probably one of the factors which accounts for this. However, new population centers and obsolescence of theaters, both in plant and location, do create a demand for new theaters. Several recent developments have greatly affected the location and seating capacity of new theaters.

Since 1945, new residential planning has tended to be in the form of large-scale, integrated communities very often decentralized. Shopping and night-life centers are then located either within the new communitiesor on the perihpery adjacent to highways. The necessities for parking areas then become a major consideration in theater location. With high land values, it is difficult for new theaters in existing urban night-life centers to provide adequate parking facilities. There has, therefore, been a tendency to locate new theaters within the confines of the new communities or in the shopping centers.

When new theaters are located within the confines of new communities, they have the ease of accessibility of the neighborhood theater. The architectural planning of residential projects very often indicates the use of several smaller theaters, with capacities in the order of 400 to 600 seats, rather than a single large theater. The smaller theaters have fewer building code restrictions and are more economical in per seat cost of construction. Their scale suggests simplicity of exterior treatment and amenities. They do have the virtue of intimacy within the interior of the theater and can achieve to the greatest degree the previous suggestions as to screen size and treatment. All of the seats can approximate the "ringside" seat. Availability of screen product and allocation of runs to groups of smaller theaters is an industry policy question of great importance.

The location of theaters within new large-scale shopping centers has different aspects. Adequate parking facilities are available, the theater plays an important part in building up night activity and there is, generally, considerable transient automobile traffic. This indicates a larger capacity theater. To achieve intimacy in the larger theater is an architectural challenge. Reduction of the interior volume of the auditorium to a minimum helps to create acoustical intimacy. Screen size is, of course, increased in the larger theater and with it, the scale of the screen surround treatment is increased. This enhances the visual intimacy which is the prime consideration. Then, the shaping of walls and ceiling, the avoidance of decoration which gives scale "measuring rods" and the integration of interior lighting must attempt to approach intimacy of space.

New and existing theaters which offer to the public the seating, air condition-

ing, projection and sound transmission comforts, which are now available, and which add to these the increased screen image, the luminous screen field, the increased flexibility and scope of motion picture cinematography, the feelings of intimacy within the auditorium, and stereoscopy of sound and vision, should survive within the forests of home television antennae which have become a feature of the skyline.

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Discussion

Pierre Mertz: Some years ago, there was a development in films which seemed to cover something of what Mr. Schlanger had in mind with regard to the wide screen —the Grandeur film. That occurred before I came into this field. Can you tell us, what was the improvement in realism with the Grandeur film as compared with the conventional film?

Mr. Schlanger: There are many factors involved. First, there was a larger physical width of film, and I believe since then the film grain problem has been more or less licked and that a sufficiently large picture can be projected from 35-mm width. The present standard gives a wide enough picture in theaters, and the real problem, which was not licked at the time that Grandeur and other wide, enlarged screens were presented, was the cinematographic problem. It is quite natural. It was a new tool and it never had its chance for the experience or practice that is needed with a new tool. In other words, the cinematographers never became familiar with the new tool or its potentials at that time. Today we are in a spot where we know we need some new method or device, and, should we find it, the cinematographers will learn to use it. As to the realism that can be achieved, there is another problem in addition to that of the size of film and the art of cinematography—that is the taking-lens in the camera. I remember getting in touch with some of the authorities and manufacturers of lenses to try to find out why there were not wider-angle lenses available or used in taking motion pictures, and the significant answer was that there was never any great demand for them. But it was possible to develop them. I do hope that they will develop wider-angle lenses, because that is another tool in the flexibility of cinematography that is necessary.

Frederick J. Kolb, Jr.: Most of the desirable features of theater design that you have discussed seem directly contrary to the requirements of a drive-in theater. Is it possible to reconcile the two?

Mr. Schlanger: Would you be specific as to their being contrary?

Dr. Kolb: I am thinking of the drive-in theater as having a very limited angle of view—more like the home television viewing conditions. Therefore the advantage to be gained by including a larger story element on the screen and by restricting the audience to the most favorable locations seems very difficult—at least, to me—to realize in drive-in design.

Mr. Schlanger: In drive-in theaters, the remote car positions are at least 10 W [W = screen width]. They are placed so because of the physical problem of getting enough attendance with one screen and I have noticed that there have been some developments recently for double screens and even four screens. I guess that is one of the problems to be overcome. From a 10 W location in a drive-in theater, the picture looks like a postage stamp. It is not that it is poorly done. It is an incon-

spicuous speck in the field of view. However, the drive-in theater is a unique experience—to be able to ride out in your car and go and view a picture is still "something different." The audience will tolerate a lot when a thing is unique enough. For example, even home television, good as it is today, falls far short of the quality of a motion picture in a theater. But it is tolerated; it is considered all right because it is unique. You can sit in your slippers, smoke a cigar and watch television without leaving your house. Getting back to your question—can you produce a picture which is just as useful in a drive-in theater as in any other theater? There is an inconsistency in this respect and it can be related also to television viewing. Due to the deficiencies in television viewing there is a tendency, and justifiably so, to use close-ups, because middle and distance shots appear indistinct. For the same reason, middle and distance shots in drive-in theater production should also be avoided. There again, a predominance of close-up shots is a desirable thing, if drive-in theaters are going to be designed with 10 *W* viewing. So, you are correct. A picture which would be photographed carefully for a drive-in would not be good for regular motion picture theaters, but there is always a happy medium. You must be sure that the close-ups are not too close up, and that the distant shots are not too distant. You have to compromise, and I believe that this could be done easily enough so that there would be neither too many close-ups for viewing in the regular theater, nor too few, for the drive-in theater.

Walter E. Dunn: You have made repeated references to the elimination of black screen masking. Do you have any recommendation for either a substitute or a system of elimination of the mask in an existing thaeter?

Mr. Schlanger: There are several methods of eliminating black masking. First of all we have to realize that black maskings were originally created for purposes which no longer exist. One was that screen illumination in the early days was comparatively low and the black masking went a long way toward making the illumination appear brighter. I think that television viewing is proving that black masking is no longer necessary. With the exception of the Du Mont sets, practically all the sets have a white or almost-white color masking. The other reason for black masking was to do something about the aberrated or fuzzy edge of the picture as it is when projected without a black masking. That is a practical problem. This aberrated, fuzzy edge can be eliminated in several ways. We have been developing a substitute masking, a luminous masking, which I think will be available very soon. We have also had other solutions in which we would cut the picture, that is, project the picture very carefully into a proscenium which was exactly the size of the picture and let it go at that, or by having a slight flare come right out from the picture. The fuzzy edge would fall on the angular surface, which would not be visible to the audience, and the picture would appear to have a clean-cut edge. Some of the newer maskings that have been developed will do an even better job.

Leonard Satz: I'd like to add to that that there are certain things which, in my opinion, can be done right now, short of making major changes. I would say, principally, modernization of lighting would be the first step in the theater auditorium—the elimination of distracting side-wall brackets, which are so common in many of our theaters, and replacement with an operating light which is directed downward and perhaps intentionally directed to the proscenium area. The first step would be, naturally, the enlargement of the screen, and I believe it is a fact that visual acuity is not lost by the reduction in screen brightness as long as the image is increased in size. You mentioned limitation of screen brightness as being one of the problems of the exhibitor today. I think that if he does lose 10% in incident illumination by enlarging his picture with existing projection equipment, the loss will be compensated by the fact that visual acuity is maintained with the larger picture.

Mr. Schlanger: It may not be exactly compensated, but certainly acuity increases with the size of the image, despite loss in light. I don't have exact figures on that, but I believe you can verify it.

Some Comparative Factors of Picture Resolution in Television and Film Industries

By H. J. Schlafly

This paper reviews and compares the quantitative meaning of the term resolution as commonly used by the television industry and the film industry. The danger of using values of limiting resolution as the sole measure of picture quality is discussed. Conversion equations are developed and tables listing numerically equivalent values of resolution are provided.

THE MERGER of electronics and photography into the corporate function of television recording has resulted in a unique situation. It is a situation which is logical and natural, but which, nevertheless, has caused misunderstandings, delays and even exasperation. The problem is simply one wherein two sciences that have hitherto been comparatively independent of each other suddenly find that they define and describe certain phenomena in terms which are not identical, but which are similar enough to be thoroughly confusing.

The ultimate objective of both television and photography is the faithful reproduction of an original scene. But, while the beginning and end products are the same, the medium and methods are widely different. Thus, it is little wonder that there are few, if any, existing experts who are so thoroughly familiar with the terminology and techniques of both sciences that they can point out in advance the areas of confusion or misunderstanding. This paper will attempt to deal with only one "area of confusion," the meaning of picture resolution as defined by terminology in current use.

A contribution by H. J. Schlafly, Twentieth Century-Fox Film Corp., 444 W. 56th St., New York 19. *Reprinted* from *Proceedings of the I.R.E.* for January 1951.

General

The resolving power of a medium or a device is a measure of the ability of that device to convert, transmit or reproduce details of the original scene. Detail, of course, is a "separately considered particular,"[1] which contributes to or is part of the whole. A device which is capable of handling more or finer detail is said to have the greater resolving power and the resulting picture has more resolution. Lack of picture resolution not only results in the subordination or complete loss of parts of the original, but also in a loss of "edge sharpness" which gives the pic-

ture a "soft" or, more correctly, a diffuse quality. The accepted method of determining resolution is to provide a scale or chart having calibrated points or steps of increasing fineness of detail and to determine the point at which the device under test breaks down in the performance of its function. The human eye itself has a certain resolving capability which is influenced by the portion of the retina being used, the spectral content of the light and the absolute value of the light energy, as well as by the optical characteristics of the lens. Each technical device which precedes the seeing process of the eye has its own resolution characteristic and contributes its part to the degradation of the original scene.

In general, the deterioration contributed by any physical device is evidenced by a gradual reduction in contrast ratio with increasing detail until a point is reached where there is no distinction between two adjacent points which did have some quality of distinction in the original. Whether this contrast ratio is measured in light energy, grains of silver deposit per area, potential difference or whatever, is immaterial. A notable exception to this gradual deterioration of resolution is the "sharp cutoff" voltage amplifier which might maintain constant amplification with increasing frequency (detail) until a certain critical or cutoff point is reached, and thereafter drop sharply toward zero output.

Comparative physical sizes play a large part in determining the point where "signal attenuation" begins to occur. Thus, so-called "aperture size," or the area within which there can be no differentiation, such as a single nerve ending in the eye, the focused scanning spot in a cathode-ray device or the grain size in a photographic emulsion, is a major contributor to the limitation of resolution. But there are many other contributing causes which do not necessarily deal with physical size, such as electrical time constants; aberrations in optical devices; phase shift in amplifiers; spectral sensitivity of emulsions, photocathodes and lenses; and, unfortunately, others.

Today both the photographic and television industries speak of the absolute limit of resolution as a measure of picture quality. Actually the evaluation of quality is so complex that measurement of one of the contributing factors is not adequate to describe the end result. Much work has been done and is being done to determine all of the factors involved.[2,3] In particular, analytical attention is being given to detail contrast ratio, random noise, brightness, and tone reproduction as well as to limiting resolution. The paragraphs which follow deal only with definitions and conversion factors for the resolution terminology in current use and should definitely not be considered as the sole measure of picture quality.

Terms

One is likely to assume that the use of the common term "lines" permits a basis for comparison between photography and television picture resolution. Such is not the case. Each industry has independently arrived at a definition in language best suited to its own measurement technique and, as a result, numerical values which are not apparently related might refer to the same degree of "absolute" resolution in a television picture and in a photograph.

The film industry defines resolution in terms of lines/mm of film surface. Typical test charts are provided by the National Bureau of Standards (shown in Fig. 1) and by the American Standards Association. Such charts usually consist of a series of blocks or squares of parallel black lines separated by clear spaces of the same width. Each block represents a given number of black lines/mm of film surface when the chart is photographically reproduced on the film emulsion. For determining resolu-

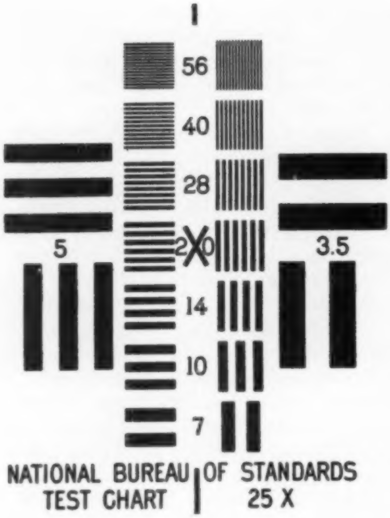

Figure 1.

tion values given in film specification sheets, the contrast ratio between the black lines and the clear spaces on the original chart is held at 30:1. Incidentally, this is about the highest value which can be obtained on a printed chart. Transmission-type charts, used in some resolution measurements, can provide contrast ratios of 100:1 or 1000:1.

The resolving power of a given film emulsion is determined by photographing a test chart using the optimum exposure, processing the film by recommended methods and examining the image under a microscope. The maximum number of black lines/mm just resolved, not lost as an indistinguishable gray mass, is the value used to indicate the resolving power of that particular film. In practice the resolving power values of commercial films vary from about 55 lines/mm for negative film to as high as 150 lines/mm for fine-grain sound recording films.

Of course, the figures given in the above paragraph do not necessarily represent the end product of film resolution as seen on the screen of a motion picture theater. In February, 1946, a portion of the Television Committee of the Society of Motion Picture Engineers made observations of screen resolution of a special test film projected in a group of leading New York theaters. These data were not published because the tests were not sufficiently extensive to permit definite conclusions. In the words of the Committee report: "The influence of many individual factors has not been determined, but it is believed that the results...are broadly representative of present motion picture practice...." The conclusion reached in the same report stated, "In general, it can be concluded from theater projection of the two test films specially prepared for the use of this Committee that projection in first-run theaters shows resolution of 28 lines/mm on 35-mm film where the test object includes pictorial subject matter and 40 lines/mm where the test card alone was photographed."

In the television industry picture resolution is usually measured with the aid of a test pattern such as the RMA Resolution Chart 1946. This chart follows the practice of using horizontal and vertical wedges rather than a series of parallel lines. The pattern is composed of a given number of alternate black and white lines of equal width which continuously converge from the wide to the narrow end of the wedge. Thus, the chart is provided with a continuously variable resolution pattern, numerically calibrated by indexing various points along the wedge. Each black and each white line is counted as an individual line, whereas in the film industry each black line only is counted as an individual line.

The resolution of the television picture is indicated by a value which represents the limiting number of black and white lines identifiable as such, not lost in an indistinguishable gray, in a verti-

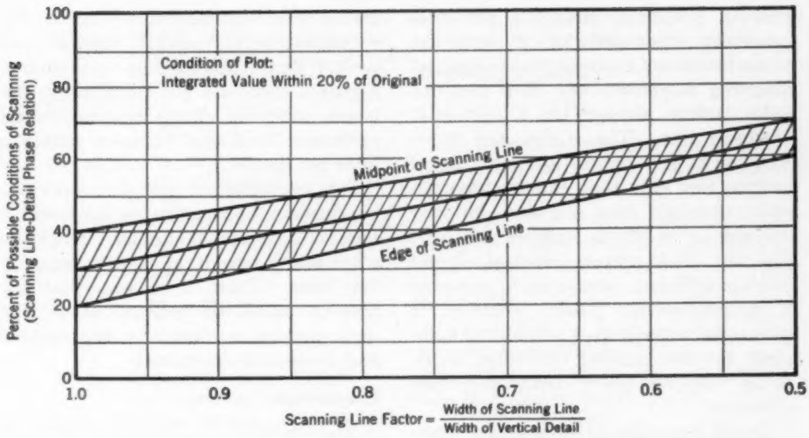

Fig. 2. Integrating effect of scanning line on vertical television resolution.

cal or a horizontal dimension equivalent to the picture height. For the purpose of assigning this value, it is assumed that the resolution of any and every point in the picture is equal to that observed at the wedge. Such an assumption is, of course, not true, but it is a convention which provides a numerical value of resolution accepted throughout the industry. Degradation at the corners of the picture sometimes is identified by the term "corner resolution" and is evaluated by the same process—interpreting the resolution of a wedge located in the corner in terms of the full dimension of picture height.

It is a common error to confuse the number of horizontal scanning lines as set by the television standards with the figure for picture resolution. The television standards in this country specify 525 horizontal scanning lines per picture frame. Only 92% to 95% of these are active scanning lines, the remainder being blanked out during the vertical sweep retrace. But even the remaining 480 some odd lines do not specify the limit of vertical resolution. There is an additional loss in vertical resolution inherent in the television dissecting process which provides a second factor even when there is perfect interlace of the alternate scanning fields. This effect is illustrated by integration of those portions of black and white resolution lines within the width of the scanning line and point by point comparison of the resulting halftone with the original.[4] Figure 2 plots such information for a range of scanning line factors, showing the percentage of possible scanning-line–resolution-line phasing for which the integrated halftone will be within 20% of the original. Choice of a scanning line factor may be a matter of individual preference but a value of 0.75 is commonly accepted and is the value used in the equation derivations included in this paper.

Using these factors, present-day standards, therefore, impose a limitation on vertical resolution of the television picture of approximately 360 lines.

Television picture resolution, by virtue of common usage among electronic personnel, has also come to be identified in terms of bandpass, or maximum pass frequency of the video circuits. Such usage has meaning only when applied to horizontal resolution and then only if a

definite horizontal scanning period is specified. One cycle of a particular video frequency during active horizontal scanning represents one dark and one light picture element on a particular scanning line. The higher the video frequency, the greater the number of picture elements that can be theoretically squeezed into one line. Ideally the one cycle which supplies the light and the dark picture element should contain sufficient harmonics to resemble a square corner pulse; actually, a sinusoidal waveform is considered sufficient for the limiting condition, sacrificing "edge sharpness" between picture elements.

It will be realized that a longer scanning period would permit more cycles of video signal to be included in one scanning line and thus the value of horizontal resolution would be increased. The scanning period is set by the horizontal scanning frequency, or, by the combination of picture frames per second and scanning lines per frame. Figure 3 indicates the relationship between video bandpass and horizontal resolution for several values of scanning lines per frame.

It is interesting to note that the video bandpass of 4.5 megacycles, the nominal television broadcast standard, results in a horizontal resolution of approximately 360 lines. Thus, it is seen that the present standards provide about the same picture resolution in the vertical and horizontal coordinates.

Conversion Factors

A. Conversion of Film Resolution in Lines per Millimeter to Television Resolution in Lines.

$$R_t = 2H_f R_f$$

where R_t = television resolution in lines per picture height

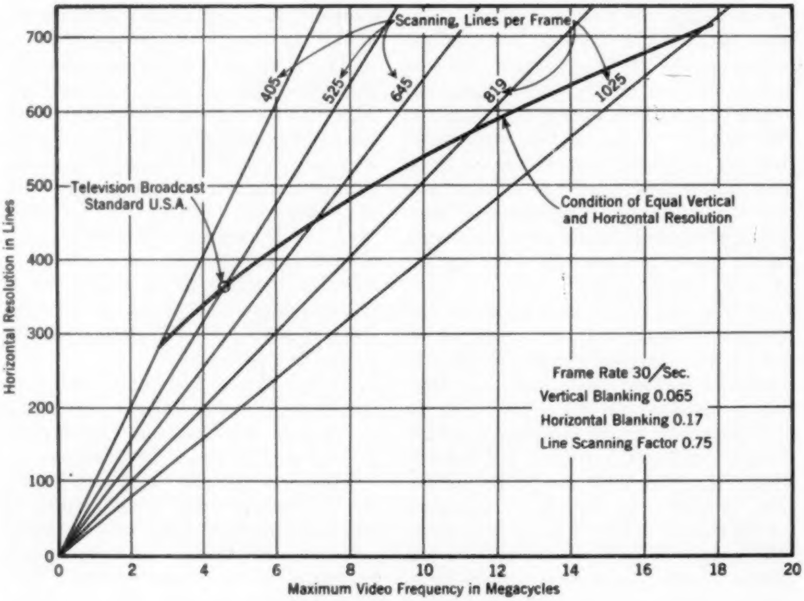

Fig. 3. Television resolution.

R_f = film resolution in lines/mm
H_f = height of standard motion picture projector aperture in millimeters.

For 35-mm film $H_f = 15.25$ mm
$R_t = 30.5\ R_f$

For 16-mm film $H_f = 7.21$ mm
$R_t = 14.42\ R_f$

B. Conversion of Television Scanning Lines per Frame to Lines of Vertical Resolution (Television).

$$R_{tv} = b(aL)$$

where R_{tv} = vertical resolution (television) in lines
a = vertical blanking factor
b = line scanning factor
L = total number of scanning lines per television frame.

Substituting present standards:
a = 0.92 min., 0.95 max., 0.935 average
b = 0.75 (representative)
L = 525 lines
$R_{tv} = 0.701\ L = 0.701 \times 525 =$ 368 lines.

C. Conversion of Maximum Video Pass Frequency to Lines of Horizontal Resolution (Television).

$$R_{th} = 2f_{max}T_h/A$$

where R_{th} = horizontal resolution (television) in lines
f_{max} = maximum video pass frequency in megacycles
T_h = active time (unblanked) of horizontal sweep in microseconds
$= C\,\dfrac{1}{L(F_r)}\,10^6\ \mu\text{sec}$

where C = horizontal blanking factor
F_r = frames per second (television)
A = television aspect ratio.

Substituting present standards:

f_{max} = 4.5 megacycles
C = 0.82 min., 0.84 max., 0.83 average
F_r = 30 frames/sec
$T_h = 0.83\dfrac{10^6}{525 \times 30} = 52.7\ \mu\text{sec}$
$A = 4/3$.

then $R_{th} = 2 \times 3/4 \times 52.7 \times 4.5$
$= 79 \times 4.5 = 356$ lines

or general formula

$$R_{th} = 79\ f_{max}.$$

D. General Conversion Formulas for Equal Resolving Power Between Film and Television.

1. Television scanning lines per frame in terms of film resolution (required for equal vertical resolution):

$$L = (2/ab)H_f \times R_f$$
$$= \frac{2}{0.935 \times 0.75}H_f \times R_f$$

$L = 43.5\ R_f$ for 35-mm film
$L = 20.6\ R_f$ for 16-mm film.

2. Maximun video frequency in terms of film resolution (required for equal horizontal resolution) in 525-line, 30-frame television system:

$$f_{max} = \left(\frac{A}{C} \times L \times F_r \times H_f \times 10^{-6}\right) R_f$$
$$= \left(\frac{4}{3 \times 0.83} \times 525 \times 30 \times 10^{-6} \times H_f\right) R_f$$

$f_{max} = 0.386\ R_f$ megacycles for 35-mm film
$= 0.182\ R_f$ megacycles for 16-mm film.

3. Maximum video frequency in terms of film resolution (required for equal horizontal resolution in a 30-frame television picture), if the number of scanning lines in that picture has been chosen to give equal vertical resolution:

$$f_{max} = \left(\frac{A}{CF_r}\left(\frac{2}{ab}H_f\right)H_f \times 10^{-6}\right)R_f^2$$
$$= \left(\frac{2A}{abC}F_r \times H_f^2 \times 10^{-6}\right)R_f^2$$

$f_{max} = 0.032\ R_f^2$ megacycles for 35-mm film
$= 0.00715\ R_f^2$ megacycles for 16-mm film.

The above equations have been applied to several values of film resolution for both 35-mm and 16-mm sound film and the results have been tabulated in Tables I and II. These tables list

Table I. 35-Mm Sound Film

Numerically Equivalent Values of Resolution		Minimum Television Standards Required for This Resolution		
Film (lines per mm)	Television (lines)	Horizontally* (video freq.)	Vertically & Horizontally (lines/frame)	Vertically & Horizontally (video freq.)
90	2740	35 mc	3900	260 mc
40	1220	15	1700	51
28	850	11	1200	25
17	520	6.5	750	9.3
11	335	4.2	475	3.9

Table II. 16-Mm Sound Film

90	1300	16 mc	1850	58 mc
40	580	7.3	820	11
28	400	5.1	580	5.6
17	250	3.1	350	2.1
11	160	2.0	230	0.9

* Provided the standard of 525 scanning lines per frame is retained.
Note: When transcribing film to television or television to film, degradation factors of each system are cumulative. To minimize over-all degradation the resolution capabilities of one system should substantially exceed that of the other. The magnitude of this "safety factor" is governed by operational techniques.

numerical equivalent values of resolution and the corresponding television standards which would be necessary to realize such a value first, of horizontal resolution (with 525 scanning lines per television frame, 30 frames/sec) and second, of both vertical and horizontal resolution (with 30 frames/sec).

These tables could be interpreted to say that, provided *all other factors affecting picture quality are equal,* a television picture having a limiting resolution of 360 lines (the approximate capabilities of the existing television broadcast standard in the United States) is equivalent to a 35-mm sound motion picture film having a limiting resolution of about 12 lines/mm; or, to a 16-mm sound motion picture film having a resolution of about 25 lines/mm. In actual practice film resolution having a limiting value of 30 to 40 lines/mm is not difficult to achieve but, on the other hand, the reproduced film picture is not able to maintain the contrast ratio that can be realized in a reproduced television picture as detail approaches the television cutoff value. Some workers in the field believe that the "other factors affecting picture quality" mentioned above may eventually be so improved in the television system that existing standards will permit a television picture quality closely approximating that of the present-day 35-mm motion picture film in spite of wide differences in the limiting value of picture resolution.

It must be emphasized again that the tables provide numerically equivalent values of resolution. They do not in themselves permit a comparison of picture quality. They in no way indicate the film resolution that is required when a film is to be reproduced over a television system or when a television picture is to be reproduced on film. It is obvious that when a film is reproduced by a television system, or vice versa, the end result will contain the defects of both. For best results, therefore, both systems should be operated as close as possible to their limit of perfection, or, in some cases, be controlled to compensate for defects or limitations of the other.[5]

Summation

Picture quality and picture resolution are not necessarily synonymous. A figure indicating picture resolution is generally a numerical measure of the limit of detail distinction. Picture quality is a function not only of the limit of detail distinction, but also of the attenuation characteristic which accompanies the reproduction of increasing detail, and numerous other factors of reproduction.

The film industry speaks of resolution as a figure indicating the maximum number of black lines, separated by white spaces of equal width, which can be identified in a dimension equal to one millimeter of film surface.

The television industry speaks of resolution as a figure indicating the

maximum number of alternate black and white lines of equal width, which can be identified in a dimension equal to the picture height.

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Image Tubes and Techniques in Television Film Camera Chains

By R. L. Garman and R. W. Lee

In this country the iconoscope is used almost universally for motion picture film camera chains. In Europe the flying-spot scanner has recently come into extensive use. Other pickup devices, storage and nonstorage, such as the image orthicon, image iconoscope and image dissector tube, have been used experimentally or in a limited commercial way. The characteristics of each of these tubes and their associated equipment are discussed, and certain advantages are evaluated with respect to such factors as signal-to-noise ratio, spurious signals, spectral response and transfer characteristic.

Since the time of the early mechanical schemes of light-spot scanning, many different techniques have been employed for producing television signals from pictures on film. A relatively short while ago, charge-storage tubes were acclaimed as a great step forward and away from the rotating-disc or rotating-drum mechanical scanners. Electronic techniques which are now being advanced as a desirable substitute for charge-storage tubes are exactly analogous to the early mechanical schemes. Historically, one development cycle seems to be complete. It is not only possible, but very probable, that further development will produce significant new advances in the art. A review of film projection methods and equipment now in use here or abroad seems very much worth while at this time.

Presented on April 25, 1950, at the Society's Convention at Chicago, by R. L. Garman and R. W. Lee, General Precision Laboratory, Inc., Pleasantville, N.Y.

In the discussion which follows, only those projector mechanisms which use a single film and a single gate are considered. More complex schemes which have been proposed are omitted, not through lack of merit, but because space does not permit their inclusion. Also, the survey of photosensitive image tubes is restricted to those commercial types which are currently available.

Projector Mechanisms and Timing Diagrams

The timing diagram of Fig. 1 indicates the nature of the basic requirements on the projector mechanism. The television vertical sweep and retrace are displayed for reference.

The television field frequency and the projector frame rate are those common to American practice, which is characterized by a conventional 24-frame/sec projector rate and a standard 60 cycle/

sec vertical sweep frequency. It may be noted that British and continental European television practice is based on a 25-frame/sec sweep standard. Conventional film, recorded at 24 frames/sec, provides very satisfactory results when played back frame for frame at this sweep frequency. The simplicity of frame-for-frame playback is not possible in this country, where the closest sweep rate that can be used for playback is 30 frames/sec. Fortunately, the television and motion picture frame frequencies are commensurable, with the motion picture frame time of 1/24 sec corresponding exactly to that of two and one-half television fields.

The usual method employed to make up for the difference in frame rates is that of scanning one film frame twice, the next three times, the next one twice, etc. Pulldown timing diagrams which accomplish this "2-3-2" method of scanning are illustrated in the last three lines of the timing diagram. The shaded areas correspond to intervals of time during which the film is in motion.

Exposure of the pickup device to light from the film entails three tasks. The first is the transition from one motion picture frame to the next. The second is illumination of the field, which must not take place while the film is in motion. The third is a raster scanning process, which may be accomplished by any one of several different methods. Some of these methods require that scanning be completed during the illumination of the field; others permit illumination of the field during a part of the scanning interval; still others do not permit illumination during any part of the scanning interval. Figures 2 to 4 provide a more detailed breakdown of the basic timing diagram with regard to these differences.

Figure 2 shows timing diagrams for film pickup systems in which the field is illuminated during the television sweep retrace time. Again, the vertical sweep and the vertical retrace period are shown for reference purposes. Illumination during the television sweep retrace time can be used with any storage-type

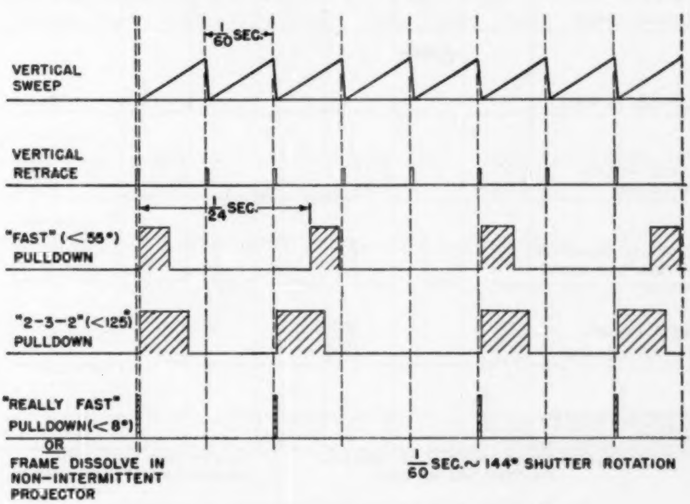

Fig. 1. Basic timing diagram for 24-cycle television projector mechanisms.

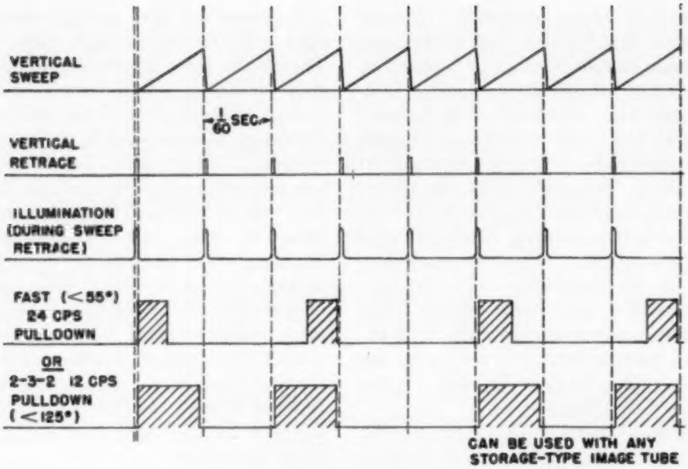

Fig. 2. Film pickup timing diagram; illumination during television sweep retrace.

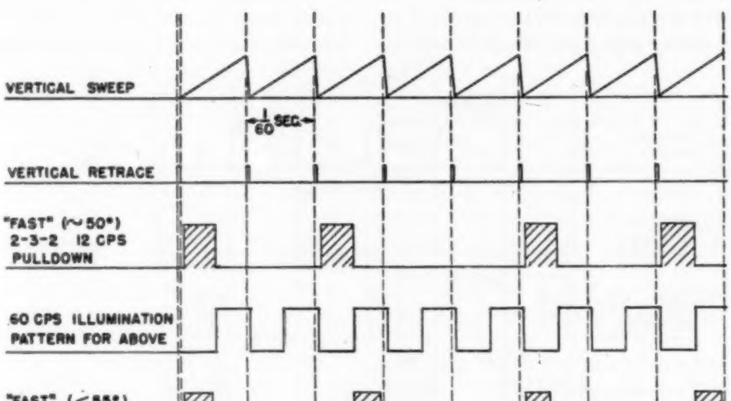

Fig. 3. Film pickup timing diagram; illumination and pulldown during television sweep.

image tube such as the iconoscope, the orthicon, the image iconoscope and the image orthicon. The relationships illustrated are typical of the mechanisms now in use in iconoscope film camera chains in this country. Two types of pulldown timing are in use, the standard 24-cycle/sec "fast" pulldown, and the "2-3-2" mechanism with a basic repetitive pattern at 12 cycles/sec, in which nearly the full television field period is available for film motion.

Figure 3 shows timing diagrams for film pickup systems in which both illumination and pulldown of film may occur during the television sweep time. This method can be used only with a storage tube which integrates linearly the light falling upon the photocathode. The only example of such a tube at present is the image orthicon, which may be used quite successfully for this application. Of course, the film may not be illuminated while in motion, or "travel ghost" will result, as in any intermittent projector without a shutter. The two bottom lines illustrate the timing for one very simple scheme, which may be used with projectors which have a satisfactorily fast pulldown (60° or less). The 120-cycle/sec illumination pattern for this scheme is generated very simply by a regular 24-cycle/sec shutter with five equally spaced slots. Unfortunately, there are extraneous photoelectric effects in the image orthicon which limit the minimum exposure time for this kind of operation. These effects are often visible as a streak across the picture, called an "application bar." The visibility of this bar is more or less proportional to the peak illumination. It is therefore advisable to increase the duty cycle of the projector. There is no strict limit, but generally the performance is acceptable if the shutter open angle is greater than 30°. A satisfactory solution is the use of a rather fast "2-3-2" pulldown mechanism with a 60-cycle/sec illumination pattern obtained from a 12-, 30- or 60-cycle/sec shutter. Inspection of the diagram will show that if the pulldown time is approximately 50° in the "2-3-2" mechanism, exposures of 70° to 80° of shutter rotation can be obtained.

Figure 4 shows timing diagrams for film camera chains in which pulldown

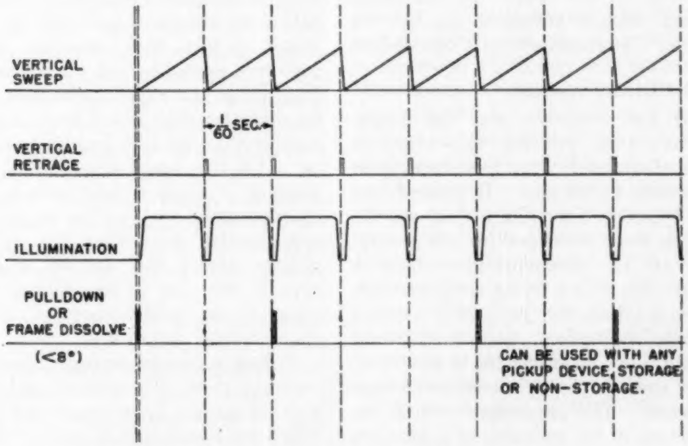

Fig. 4. Film pickup timing diagram; pulldown during television sweep retrace.

occurs during the television sweep retrace time. This mode of operation can be used with any photosensitive pickup device, storage or nonstorage. The illumination must properly be interrupted every 1/60 sec in order to provide equal exposures for each television field scan. If a nonintermittent projector with lap dissolve from one frame to the next is used, continuous illumination is possible. It may well be that, even in the case of the intermittent projector, film travel might be so fast that "travel ghost" would not result from illumination during the retrace time. This possibility may have more than merely academic interest. Ten years ago most engineers were convinced that an intermittent projector with pulldown during the retrace time was not only impossible, but fantastic and ridiculous. This is not the case today. Mechanical intermittent mechanisms which are simple extrapolations of conventional design are now available, and will pull down film in approximately 15° of shutter rotation. Audible noise problems are often acute with these mechanisms. Completely new approaches to the problem now give promise of providing pulldown in less than the minimum vertical retrace standard set by the Federal Communications Commission!

Tube Characteristics

The film projector and the image-sensitive tube are the two elements which distinguish film operations from live studio techniques. In general, the tube types used for film pickup are the same as those developed for live pickup. They are the photomultiplier (used in conjunction with a flying-spot scanner), the image dissector (preferably with an electron multiplier), and the several storage tubes including the iconoscopes, image iconoscopes, orthicons and image orthicons. The parameters which are important in the selection of a tube are signal-to-noise ratio, transfer characteristic, freedom from spurious signals, spectral response and sensitivity. Resolution capability is equally important but will be disregarded in this discussion because of the lack of good data on which to base conclusions.

It is extremely important to recognize that the signal-to-noise ratio and the shape of the transfer characteristic cannot be considered independently in arriving at a real evaluation of obtainable picture quality. The signal-to-noise ratio, measured as the ratio of peak signal to rms noise, is very much affected by the nature of the transfer characteristic of the over-all system, as well as by the noise distribution over the range of light flux utilized. Schade[1] has provided an excellent discussion of the relations between these parameters.

In commercial motion picture practice, an over-all gamma from scene to screen of approximately 1.6 or 1.7 is considered desirable from the audience point of view. It seems likely that the same objective also applies to television practice. In this case, however, the transfer characteristic of the kinescope, direct view or projection, is a power law with an exponent which probably falls in the range 2.0 to 2.8. Ideally, the transfer characteristic from scene illumination to kinescope-grid driving signal should, in turn, be a power law with an exponent probably not exceeding 0.75. In order to compare camera-tube transfer characteristics, it will be necessary to assume that the line amplifiers are linear. On this basis, the present studio practice of using a tube with a linear characteristic, such as the image orthicon, results in raising the effective gamma above the desired objective, even in the case of live pickup where there is no modification of transfer characteristic due to film.

Ordinary motion picture film can be assumed to have been processed to the over-all gamma figure mentioned above. When an iconoscope is used with such film at the illumination levels which are now common in film camera chains, the

result is an approximately linear transfer characteristic to the grid of the kinescope. In this situation, some transfer characteristic correction is probably desirable. When a tube with a linear characteristic is used in combination with the same type of film, the effective transfer characteristic to the grid of the kinescope has a power law exponent of about 1.6. The over-all transfer characteristic to the screen of the kinescope then has the extremely high power law exponent of 3.5 to 4.5. Hence, the use of some form of gamma correction is apparently mandatory when linear devices are used with normally processed film.

As an alternative, film which has been specially processed for use with linear image pickup devices may be considered. However, film processing to an effective gamma of 1.0 is probably the minimum feasible. Such film would give, again, an approximately linear characteristic to the grid of the kinescope and would result in about the same effective over-all gamma as in the case of present studio cameras on live pickup. Such special processing is probably feasible for very large television stations, or for network operations, where the capital available and the magnitude of the operation may enable complete specification and control of all steps in film production. However, as a general approach to the problem of film camera chain design, it cannot be assumed that specially processed film will always be available. Any such design will therefore have to include provision for gamma correction, and again must consider the effect of gamma correction on the system noise level.

In any image tube, there is a noise level set by the fundamental photocurrent associated with the first stage of the process. The noise current, I_{np}, for a given photocurrent, I_p, in a bandwidth, Δf, is given by:

$$I_{np} = \sqrt{2eI_p\Delta f} \qquad (1)$$

where e is the electronic charge $= 1.59 \times 10^{-19}$ coulomb.

For a 4.25-mc bandwidth,

$$I_{np} = 1.16 \times 10^{-6} \sqrt{I_p} \text{ amp.} \qquad (2)$$

Figure 5* illustrates this noise characteristic, which is typical of an ideal pickup device and is approached by the photomultiplier. In the case of storage tubes, the noise level associated with other stages—scanning beams, amplifier input circuits and the like—masks the fundamental noise level almost completely. This case will be discussed in more detail in connection with storage-type pickup tubes.

Storage-Type Pickup Tubes

Since the iconoscope,[3] the orthicon,[4] the image iconoscope[5] and the image orthicon[6,7] have been adequately described elsewhere in the literature, their construction and general mode of operation need not be reviewed here. We may proceed directly to a consideration of those characteristics which are particularly important for the film chain problem.

Table I contains data from a number of sources, both published[7,8] and unpublished, on camera tubes available at present. The Aeriscope and Photicon entries are based on manufacturers' information which has been supplied to the authors. Some obsolete tube types are included for comparison purposes. It may be noted that a very wide range of characteristics is tabulated.

The smallest of the tubes is the Aeriscope, an image iconoscope manufactured by Radio Industrie, in France, having a photosensitive area of exactly the same size as the 35-mm film frame. The Photicon, which is manufactured by Pye, Ltd., of Cambridge, England, is also quite small, having an area less than one square inch. On the other hand, the mosaic area of the

* Similar to curves which may be found in Ref. 2.

Table I. Television Camera Tube Data.

Tube Type	Photosensitive Surface					Highlight Illumination (max. ft-c)	Total Lumens (max.)	Signal-to-noise Ratio*
	Height (in.)	Width (in.)	Area (sq ft)	Sensitivity $\mu a/lm$	Spectral Response			
1850A (iconoscope)	3.56	4.75	0.117	7	Approx. Panchromatic	10	1.17	65
1848 (iconoscope)	2.25	3.0	0.047	7	Approx. Panchromatic	10	0.3	35
1840 (orthicon)	1.75	2.31	0.028	10	Approx. Panchromatic	4	0.11	130
Aeriscope (image iconoscope)	0.63	0.84	0.0037	50	Eye Curve	1.6	0.006	"Very Good"
Photicon (image iconoscope)	0.81	1.08	0.0063	60	Eye Curve	4	0.025	65
Flashed Photicon (image iconoscope)	0.81	1.08	0.0063	60	Eye Curve	1.6	0.01	65
5655 (image orthicon)	0.96	1.28	0.0085	6	Blue Peak	0.3	0.0025	70
2P23 (image orthicon)	0.96	1.28	0.0085	20	High Red	0.07	0.0006	35
5820 (image orthicon)	0.96	1.28	0.0085	40	Eye Curve	0.012	0.0001	35
5826 (image orthicon)	0.96	1.28	0.0085	40	Eye Curve	0.05	0.00043	70

* Ratio of peak signal to rms noise.

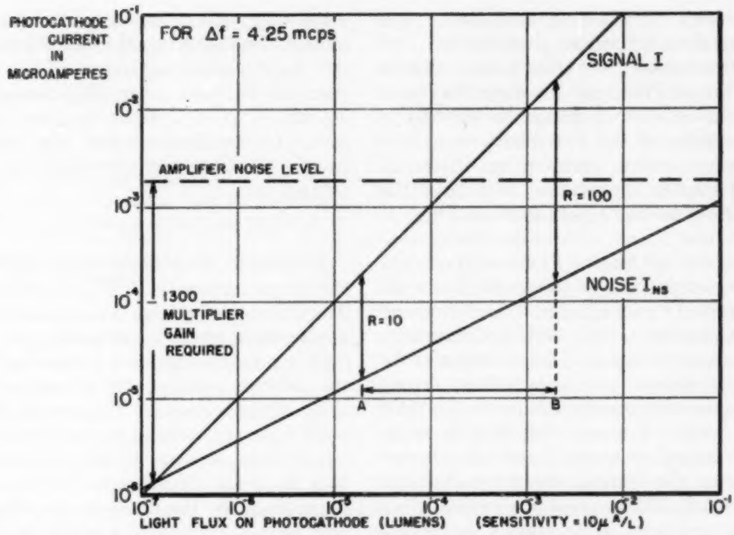

Fig. 5. Noise characteristics for an ideal pickup tube. (From *RCA Review*[3])

1850A, the iconoscope most commonly used at present in film camera chains, is approximately 17 sq in.

The sensitivities of the photo surfaces vary by a factor of approximately ten, the highest figures being obtained in the newest tubes, namely, the 5820 and 5826 image orthicons and the European image iconoscopes. These same tubes also offer an advantage in that the spectral sensitivity curve of the photo surface very closely approximates the eye sensitivity curve, and hence enables very satisfactory operation with white light and color film.

Tube sensitivity is normally specified in terms of the highlight illumination required on the photocathode. This form of specification is not very satisfactory for the television camera designer. The sensitivity of any photosensitive image device is more conveniently measured in terms of total light flux required to give a picture with a specified signal-to-noise ratio, from a definite angular field of view, and with a specified depth of field.[9] Tube handbooks do not, of course, furnish information in this fashion, nor is there much indication of the signal-to-noise ratio attainable. In the case of pickup from film, depth of field is not an important criterion, but a knowledge of the total luminous flux required on the photo surface (independent of the picture size) is pertinent to any projector design. The luminous flux required for each of these tube types is therefore tabulated as the product of the known area of the photosensitive surface and the nominal maximum highlight illumination required. Approximate signal-to-noise ratios, in terms of peak-to-peak signal relative to rms noise voltage for a 4.25-mc bandwidth are also tabulated.

Maximum luminous flux and signal-to-noise ratio figures are illusory in one sense. For example, there is no strict limit on the illumination in the case of the iconoscope. Present practice, as a matter of fact, provides a highlight illumination of 40 to 75 ft-c on the mosaic of the 1850A in most film camera chains. On the other hand, the image

orthicon illumination is more or less limited to the values given.[8]

One entry in this table, labeled "Flashed Photicon" for want of a better term, refers to a particular method of operation of the Pye Photicon in film chains, rather than to a distinctly different type of tube. Details of the method are to be published elsewhere in the near future. However, the general features are known to the authors and are outlined herein by permission of R. Theile of Pye, Ltd., and F. H. Townsend of Cathodeon, Ltd., both in Cambridge, England, to whom acknowledgment for development is made. The timing diagram is basically similar to the third line of Fig. 2, except that flash illumination as well as image illumination occurs during the vertical sweep retrace time. The flash illumination is provided by an auxiliary lamp which floods the photocathode with light during the initial portion of the retrace interval. The resulting photoelectrons provide a uniformly distributed electron shower over the entire surface of the mosaic. Simultaneously, the collector electrode is pulsed negative so that secondary emission is not collected from the mosaic, which then becomes negative relative to the normal collector voltage. The collector returns to normal potential immediately following the light flash, and hence is appreciably positive with respect to the mosaic during image illumination and subsequent beam scanning. With a positive collector, sensitivity is increased and shading problems due to secondary electron redistribution are less acute. It is recognized that this kind of operation is possible only with intermittent exposure of the camera tube, as is the case in most film camera chains.

Noise Considerations in Storage-Type Pickup Tubes

The image orthicon represents the nearest approach to an ideal storage-type pickup tube. As was pointed out previously, the photocurrent noise is almost completely masked by the noise due to the scanning beam. The relationship between scanning-beam-noise current, (I_{nb}), and scanning-beam current, (I_b), is identical with that given for the photocurrent noise and can be written as:

$$I_{nb} = 1.19 \times 10^{-6} \sqrt{I_b} \qquad (3)$$

In the case of an ideal image orthicon, the beam current is 100% modulated. The beam-current noise is a maximum in the black, where the return beam current is a maximum, and a minimum in the whites, where the photocurrent noise is a maximum. This results in a total noise characteristic which is virtually independent of illumination level, and in noise fluctuations which are approximately the same in the blacks and whites. Practically speaking, the image orthicon falls short of this performance because the efficiency of beam modulation is not greater than about 25% or 30%. A very large part of the noise output from the tube is therefore due to the unmodulated beam noise. These relationships are illustrated in Fig. 6,* in which the inherent noise level for an ideal pickup device, the noise level for an ideal image orthicon, and the total noise actually obtained from an image orthicon are all plotted as a function of light flux on the photocathode. It will be noted that the signal current and the inherent noise current are double the values shown in the previous figure, to account for the secondary emission multiplication of approximately 2, which occurs at the target.

In the case of iconoscopes, orthicons and image iconoscopes which do not contain signal multipliers, the noise level is set by the associated amplifier noise level. The equivalent input noise, I_{at}, to an amplifier with a bandwidth, Δf, and a response characteristic which is

* Similar to curves which may be found in Ref. 2.

flat and independent of frequency over that bandwidth is given by[10]:

$$I_{nt} = 2\sqrt{\frac{kT}{R}\Delta f\left(1 + \frac{R_t R(\omega C)^2}{3}\right)} \quad (4)$$

where: k = Boltzmann's Constant
T = absolute temperature
R = input resistance
R_t = equivalent input resistance due to shot noise in the first amplifier
C = shunt capacity in the input circuit.

This amounts to approximately 2.6×10^{-9} amp for a flat 4.25-mc bandwidth.

It is usually possible to increase signal-to-noise ratio by using a fairly large load resistance. However, because of the associated capacity of the tube and input circuit, frequency compensation is required. It is necessary to peak the amplifier response characteristic to give a response which is proportional to frequency over the bandwidth. The equivalent input noise for a peaked-channel amplifier, (I'_{nt}), has been given by Schade[1] as:

$$I'_{nt} = 3.7 \times 10^{-19}(\Delta f)^{3/2} \quad (5)$$

which for a peaked 4.25-mc channel is approximately 3.4×10^{-9} amp. However, although the measured noise current for this peaked channel is numerically greater than that given for a flat-channel amplifier, the effect on the eye is actually less. This has been noted by Schade,[11] who has produced experimental curves for the detail response characteristic of the human eye. He has shown that, because of the fine grain of the fluctuations associated with a peaked-channel amplifier, the effective noise current for a peaked channel is approximately one-third of the calculated noise current for a flat 4.25-mc channel. The effective noise level in such a channel is therefore reduced by the eye characteristic to approximately 1.1×10^{-9} amp.

Table II presents data on the transfer characteristic and the total luminous flux required for an effective signal-to-noise ratio of 35, for several of the tubes listed in Table I. The total luminous flux at maximum rating is listed for reference. On this basis, the iconoscopes and image iconoscopes offer a very much larger effective signal-to-noise ratio than is obtainable with either of the image orthicons, which have a much lower storage capacity and a flat-channel noise characteristic.

Summary of Storage-Type Pickup Tube Characteristics

The iconoscope can give a very good signal-to-noise ratio when used in a system having the proper transfer characteristic, but it presents difficulties with shading and bias lights, and does not have as good a spectral-response characteristic as might be desired. The image iconoscope is more sensitive, has fewer difficulties with shading, does not require edge or bias lighting, can give just as good a signal-to-noise ratio, and offers a very good spectral-response

Table II. Transfer Characteristic and Effective Sensitivity of Television Camera Tubes.

Tube Type	Power Law Exponent of Transfer Characteristic	Total Lumens at Max. Rating	Total Lumens for Effective Signal-to-Noise Ratio of 35
1850A	0.7	1.17	0.041
1848	0.7	0.3	0.03
1840	1.0 (linear)	0.11	0.0098
Photicon	0.7	0.025	0.002
Flashed Photicon	0.7	0.01	0.001
5820	1.0 (linear)	0.0001	0.0001
5826	1.0 (linear)	0.00043	0.00012

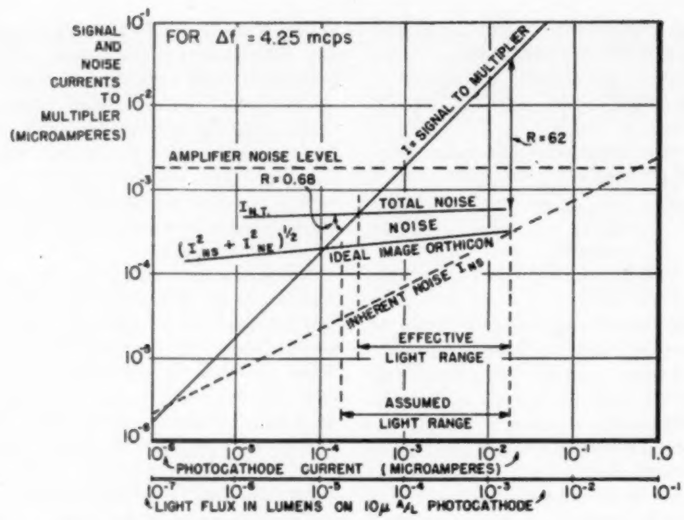

Fig. 6. Noise characteristics of image orthicons and iconoscopes. (From *RCA Review*[3])

curve. The image orthicon is extremely sensitive, requires no shading adjustments by the operator, and in the newer types has a good spectral-response curve; however, its signal-to-noise ratio is not very good when the transfer characteristic required for pickup from film is considered. In terms of picture quality obtainable with storage-type camera tubes, the image iconoscope seems to rate first, the iconoscope second and the image orthicon third. However, the image orthicon must not be discounted where low operating cost, rather than attainment of the very highest picture quality, is of prime importance. Ease of operation, and the relatively simple nature of the associated projection equipment are useful properties for low-cost operation. It is quite feasible to consider a projector used on the studio floor with an ordinary studio image orthicon camera which is dollied up to the projector for film commercials and programs. There are, in fact, many kinds of film operations for which the image orthicon camera will give perfectly acceptable picture quality, at low operating cost.

Nonstorage-Type Pickup Tubes

The earliest mechanical schemes of light-spot scanning, as applied to film pickup, utilized a rotating disc or drum as the source of the light spot and a photocell as the sensing, or transducing, element. The modern flying-spot scanner, using a special cathode-ray tube as the source of the light spot, and substituting a photomultiplier for the diode photocell, is now widely recognized as a device which can provide very high quality signals from film. The multiplier-type image dissector tube is also familiar to television engineers, and can produce excellent television pictures, but to date has received less publicity.

By their nature, these nonstorage pickup devices require continuous illumination of the photosensitive surface during the scanning of the picture. Hence, their use is confined either to

continuous-motion projectors, or to those intermittent projectors in which film pulldown is completed during vertical retrace of the television scan. Unfortunately, neither projector has as yet been successfully applied to pickup from motion picture film in this country.

The necessity of scanning in 2-3-2 sequence, dictated by the difference between television and motion picture frame rates in this country, very seriously complicates the problems of the continuous-motion projector. In England and Europe, where frame-for-frame playback is ordinarily used, the results obtained with a continuous-motion projector and the flying-spot-scanner technique are startlingly good.

Where frame-for-frame playback is possible, the flying-spot-scanner technique applied to pickup from continuously moving film offers some advantages over other methods of pickup. Adjustment of the centering, amplitude and linearity of the raster on the scanner tube allows compensation of certain types of imperfection in film motion. Experimentally, it has been found that the film velocity can be made sufficiently uniform to maintain good interlace and vertical resolution. Very high quality television pictures are obtained from film in this manner in equipment manufactured by the Cinema Television Co., and Electrical and Musical Industries, Ltd., in Great Britain, and by Radio-Industrie in Paris.

The photomultiplier in this application constitutes a nearly ideal pickup device with a noise characteristic similar to that shown in Fig. 5. The highlight flux required for a very high signal-to-noise ratio is about 10^{-3} lm, which is not difficult to obtain from a high-voltage scanning tube especially designed for the purpose.

The scanning tube presents more serious problems, such as the problem of phosphor "grain." Grain results in signal fluctuations which, on close inspection, are seen to be nearly stationary on the raster. Experimental scanning tubes have been built which are relatively free of this defect, but such tubes are not as yet commercially available. Another problem is created by the phosphor-decay time of current tubes. Light output from the phosphor should decay to a low value in a fraction of a microsecond; otherwise light is collected from points along a line behind the flying spot, instead of from the spot alone, and streaking and loss of resolution result. Although it is possible to compensate for slow phosphor decay by proper shaping of the frequency response curve of the amplifiers, the results are not always optimum. Still another problem is due to phosphor color. The light output should be essentially white to enable faithful reproduction of tonal values from color film. To date, the only phosphors found useful for flying-spot-scanner tubes have suffered the defect that the luminous spot is colored green, blue or violet.

The principle of the image dissector tube is illustrated in Fig. 7. A steady and continuously illuminated picture is projected on the photocathode. By conventional television deflection techniques, the photoelectrons emitted from the photocathode are scanned across the stationary rear aperture and amplified by a more or less conventional electron multiplier. The projector may use either continuous film motion or rapid intermittent pulldown. The image dissector tube has the distinct advantage that there is no difficulty in rendition of color film, since a standard projector light source (tungsten or carbon) may be used. For the same reason, it is not difficult to obtain the light flux required (which is greater than that needed for the flying-spot scanner by a ratio equal to the number of picture elements scanned).

A comparison of flying-spot-scanner and image-dissector techniques is difficult because a consistent analysis must

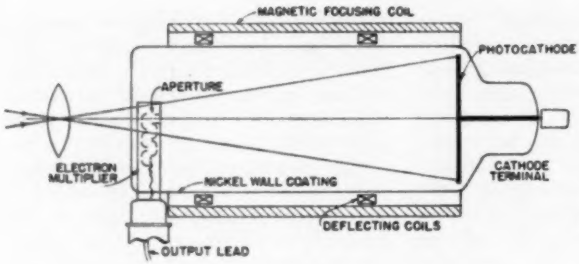

Fig. 7. Principle of the image dissector.

assume projectors developed beyond the point where they stand today. As a personal opinion, the authors submit that the continuous-motion projector will not be the solution; previous attempts do not seem to have yielded a steady enough picture for the dissector tube, and in the case of the flying-spot scanner the problem of conversion from 24 to 30 frames/sec seems to be an insurmountable obstacle. No intermittent projector capable of pulling film into register during the television field retrace time is now available. However, in view of the many development groups at work on the problem, a satisfactory solution seems inevitable. Once such a projector is available, both flying-spot-scanner and image-dissector techniques will offer very interesting possibilities for generating high-quality television pictures from film. Both techniques promise ideal noise characteristic, complete freedom from shading problems, and relatively high sensitivity. At the present time, with projector mechanisms which are available, storage-type pickup tubes offer the only feasible solution.

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Characteristics of All-Glass Television Picture Bulbs

By John L. Sheldon

Discussed are methods of manufacturing glass television bulbs, together with engineering data on mechanical, dimensional, optical and electrical characteristics of bulbs and glass. Current trends are given for size, shape and deflection angle.

As an engineering material, glass has an extraordinary versatility and range of useful properties. The important uses in motion pictures and television are too numerous to recite here, except to say that without glass it is difficult to see how the two industries could exist. In the case of television bulbs the properties of glass that are of particular importance are optical clarity, electrical characteristics and high-vacuum properties.

Although picture-tube bulbs may be made of a combination of glass and metal, this paper will deal only with the all-glass type, which predominate in the industry today. Glass is basically a very cheap material and thus is a desirable one on which to base a large volume item that must sell in a narrow-margin, competitive field. In addition to the fundamental price factor, glass is an electrical insulator and serves not only as the vacuum container, but permits the tube to be mounted in the set cheaply and with little danger of electrical leakage.

Presented on October 16, 1950, at the Society's Convention at Lake Placid, N. Y., by John L. Sheldon, Development and Research Dept., Corning Glass Works, Corning, N. Y.

Method of Manufacture

Glass bulbs for small cathode-ray tubes, such as are used in oscilloscopes, are generally made by blowing in one piece. However, it is difficult to get the glass distribution and surface quality required for large bulbs by a blowing method. Therefore present-day large bulbs are made by a process which was originated by Corning Glass Works,[1] the first large-scale application being the production of large quantities of cathode-ray bulbs used during the war in radar equipment.

Briefly, the present method of manufacture consists in sealing together three separate parts. In Fig. 1 are shown the parts from which the popular 16⅝-in. rectangular bulb are made. The panel is made by pressing, which insures accurate control of face thickness and curvature. The middle section, or funnel, also may be made by pressing, or by a process of centrifugal casting. Cast funnels have the advantage of less

weight. Drawn tubing is used for the neck, thus satisfying the rather stringent requirements imposed by close-fitting components that must slide over the neck, as well as the need for ample electron beam clearance inside. Further, an accurate, round bore insures accurate alignment of the electron gun.

A #4 Alloy "button" is sealed into the side of the funnel with fully automatic machinery. It serves to make contact with the conductive coating which is on the inside of the bulb. Successful button sealing goes back to the manufacture of the alloy. The analysis must be within close limits, as well as the expansion coefficient. Also, it must have proper oxidation characteristics. Before use, the button must have a special cleaning, followed by oxidation in wet hydrogen at about 1200 C. The oxide that is produced bonds to the glass during sealing to form a strong, vacuum-tight joint.

Formerly the three separate parts were joined by welding with gas fires. We now employ an electric method[2] for sealing panel and funnel together. It has the advantage that heat is generated within the glass, rather than "pushed" in from the outside. Also, the method is fast and easy to control, hence it is very well suited for mass manufacture. The result of electric heating is a seal that has excellent geometry and strength.

Because the finished tube is evacuated, and thus subject to external pressure, it must be strong. A factor of safety is necessary to guard against breakage when the tube is mishandled. Therefore it is customary to design bulbs to withstand a pressure of three atmospheres.

Glass Characteristics

One of the important developments of the past two years has been that of a new lead-free glass designed particularly for mass-produced picture bulbs. During the war lead glass was used for radar cathode-ray oscilloscope bulbs, partly because high electrical resistivity was needed. Lead has been an expen-

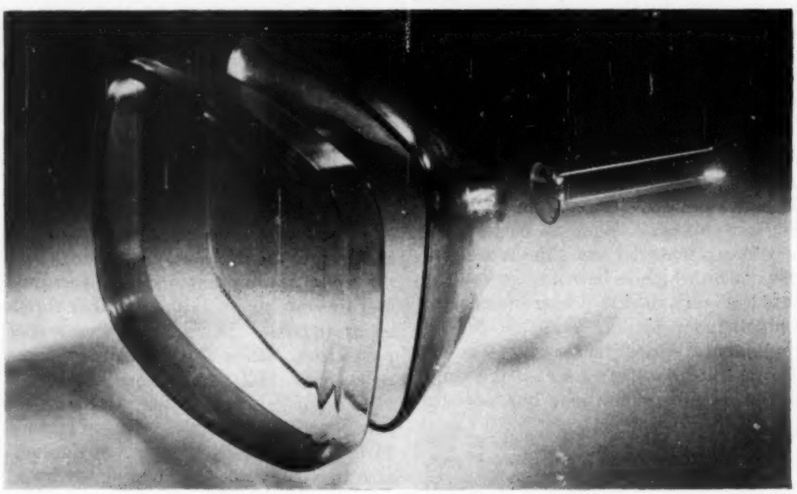

Fig. 1. Separate parts that are sealed together to make a bulb.

sive and uncertain material and because a substantial percentage was used, the bulbs were heavy.

A glass completely free from lead is of particular importance at this time when it is almost certain that restrictions will be placed on lead and other strategic materials. This is doubly important in view of the accelerated electronics program. Radar tubes can be made from lead-free glass to advantage; in fact, the optical quality of future radar tubes will be far better than those used in the last war. Military radar will also benefit from other substantial advances made in glass technology. During World War II most of the panels for radar bulbs were made by the laborious method of hand pressing. Now, high-speed pressing of 20-in. panels is routine.

The new glass (Corning Code 9010) was tailored to the exacting requirements of television. It has a high electrical resistivity, is 15% lighter than the lead glass formerly used (Corning Code 0120) and can be readily melted to give the exactingly high quality that is demanded in picture-tube panels. In Table I are some engineering data.

Table I

Density	2.59
Refractive Index (N_D)	1.506
Coefficient of Expansion (Average 0–300 C)	88.5×10^{-7} cm/cm/°C
Electrical Resistivity	
350 C	log 7.0 (ohms/cm)
250 C	log 8.9 (ohms/cm)
Softening Point . .	650 C
Annealing Point . .	442 C
Strain Point	411 C

Although it is important to control the properties of all electronics glass within narrow limits, this is particularly vital for television picture bulb glass. Close control of the expansion coefficient is dictated by the method of bulb manufacture, which requires very large seals between relatively thick "high" expansion glass. In this operation, two glass-to-glass and one glass-to-metal seals are required. Much of the time the separate parts are produced from different tanks. A third glass-to-glass seal is made by the tube manufacturer. Not only is expansion important, but so also are the viscosity characteristics. The "stem" carrying the electron gun is joined to the neck with a "drop" seal, in which the heated neck-glass is pulled down around the stem by gravity. This high-speed, automatic operation is dependent on close control of glass properties.

High electrical resistivity is desirable for several reasons. First, the full anode voltage appears across the wall of the neck tubing, from the inside conductive coating to the external components which are at ground. Second, in many types the outside of the funnel is coated with a conductive paint. Thus, the bulb also serves as a filter condenser, the glass wall being the dielectric. Last, if the resistance were low, then the tube mounting would have to be a good insulator to prevent excessive electrical leakage through the glass to ground. This would increase set cost.

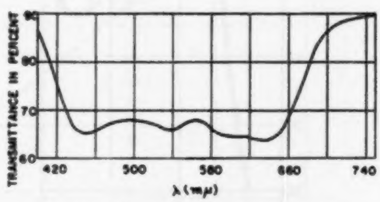

Fig. 2. Transmittance curve for Corning 9010 neutral-gray glass.

The first lead-free glass to be used was "clear." However, following an extensive program of development with the tube industry, a neutral gray version was offered in 1949. The spectral transmittance is shown in Fig. 2. Use of a

neutral absorbing glass minimizes the loss of contrast due to ambient light that falls on the screen.[3] This was an important contribution, because of the trend toward viewing television in lighted rooms and, also, because of the increase in the number of daytime programs. An absorbing glass also minimizes loss of contrast due to halation, which is the result of internal reflections within the face.[4]

At present there is an industry standard for luminous transmittance and chromaticity which was agreed upon by the Joint Electron Tube Engineering Committee (JETEC) of the RTMA (Radio and Television Manufacturers Assn.). For 10½-in. and 12½-in. bulbs the luminous transmittance is 66 ± 3%. The chromaticity is defined by use of the International Commission on Illumination color system. In Fig. 3 is shown a nominal spectral emission curve for the P4 7000° white phosphor used in television tubes, while Fig. 4 shows the tolerance area for chromaticity. The nominal chromaticity of the standard P4 phosphor-gray glass combination is $x = 0.3044$ and $y = 0.3177$, with a tolerance area as shown in Fig. 5. Considera-

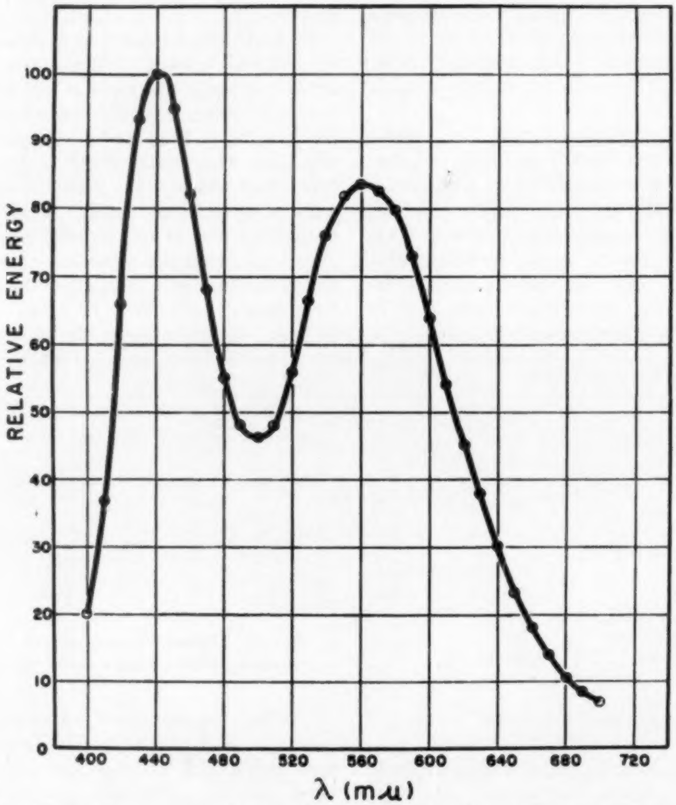

Fig. 3. Spectral energy emission characteristics of typical 7000 K all-sulfide P4 screen.

tion is currently being given to standardizing larger-sized bulbs.

Trends in Bulb Design

The phenomenal growth of television is matched only by the equally rapid rate of change within the art—a rate so great as to make most written material out-of-date before it can be published.

1. Size. In 1948 the 7-in. electrostatic and 10½-in. electromagnetic round tubes were the large-volume types. They were supplanted by the 12½-in. round tube in 1949, which in turn has become practically obsolete, being followed by 16-in. and 19-in. round bulbs. This evolution is shown in Fig. 6.

The ready acceptance of larger and larger pictures brought about the practice of "overscanning," which resulted in a picture with straight top and bottom sides, but with circular ends. While this increased the utilization of available screen area, there was a loss of the information in the corners and a departure from the 4:3 rectangular shape. This subject was recently discussed by Bretz.[5]

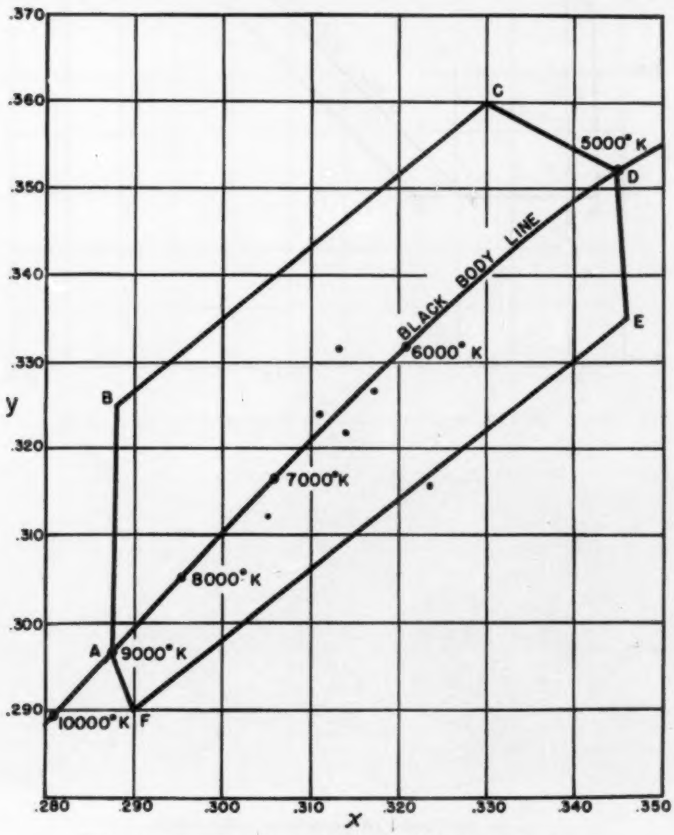

Fig. 4. JETEC color limits for P4 white phosphor.

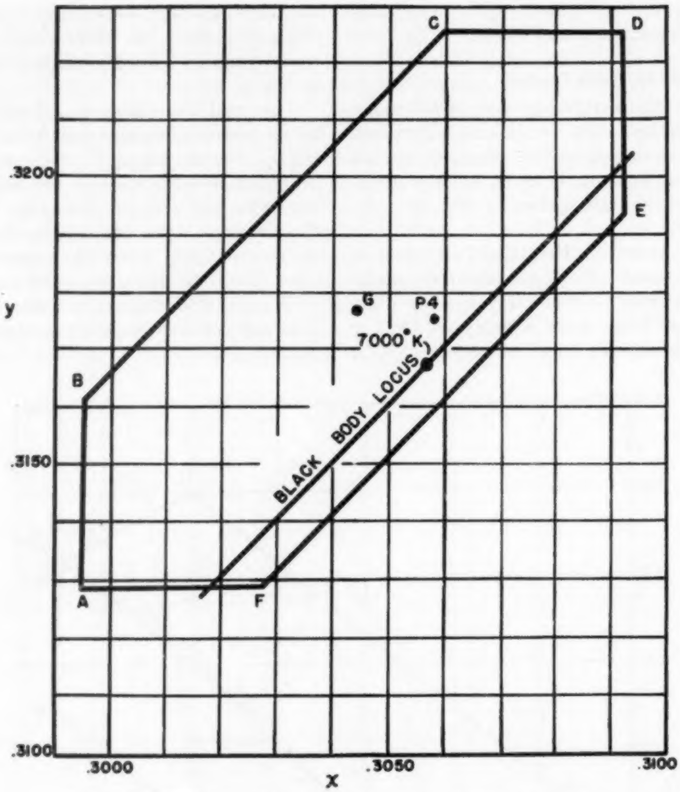

Fig. 5. JETEC specifications for neutral filter face glass.

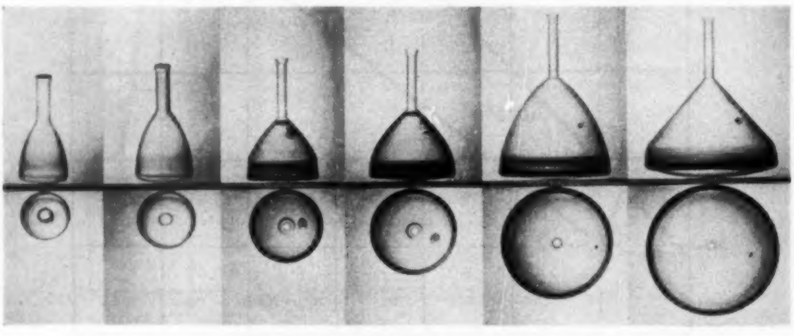

Fig. 6. Trend of bulb size, 1948–1950.
From left to right, 7-in., 8½-in. (both blown bulbs), 10½-in., 12½-in., 15⅞-in., 18⅞-in.

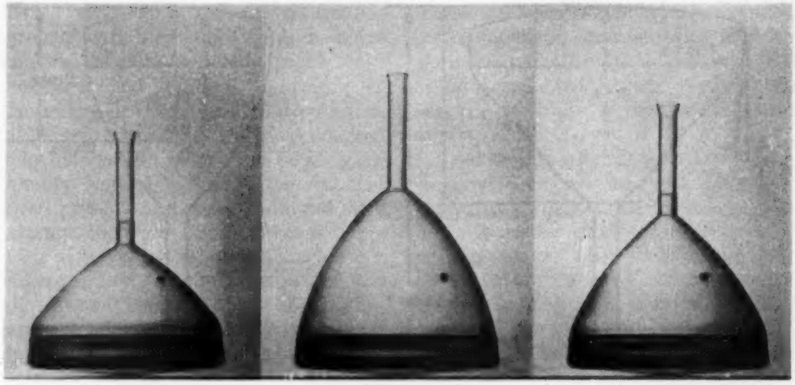

Fig. 7. Three 15⅞-in. bulbs
Left to right, 70°, 52° and 60° deflection angles.

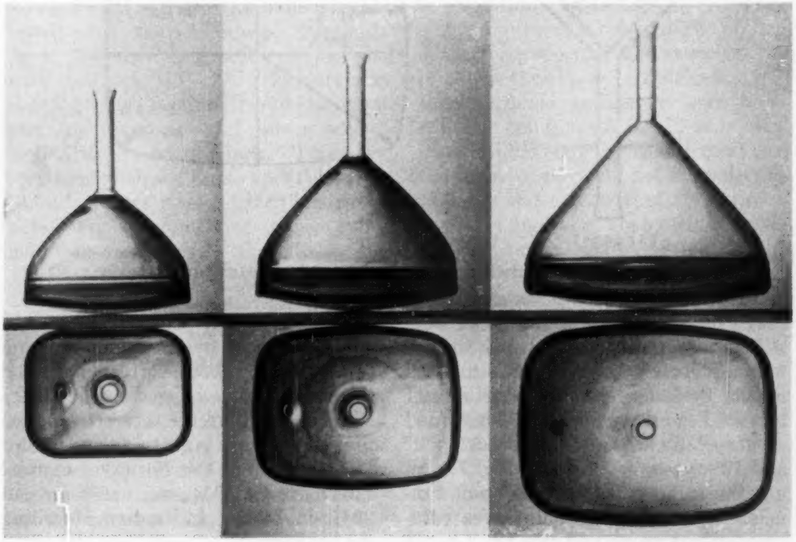

Fig. 8. Rectangular bulbs
Left to right, 13$\frac{11}{16}$-in., 16⅝-in., 20$\frac{3}{32}$-in.

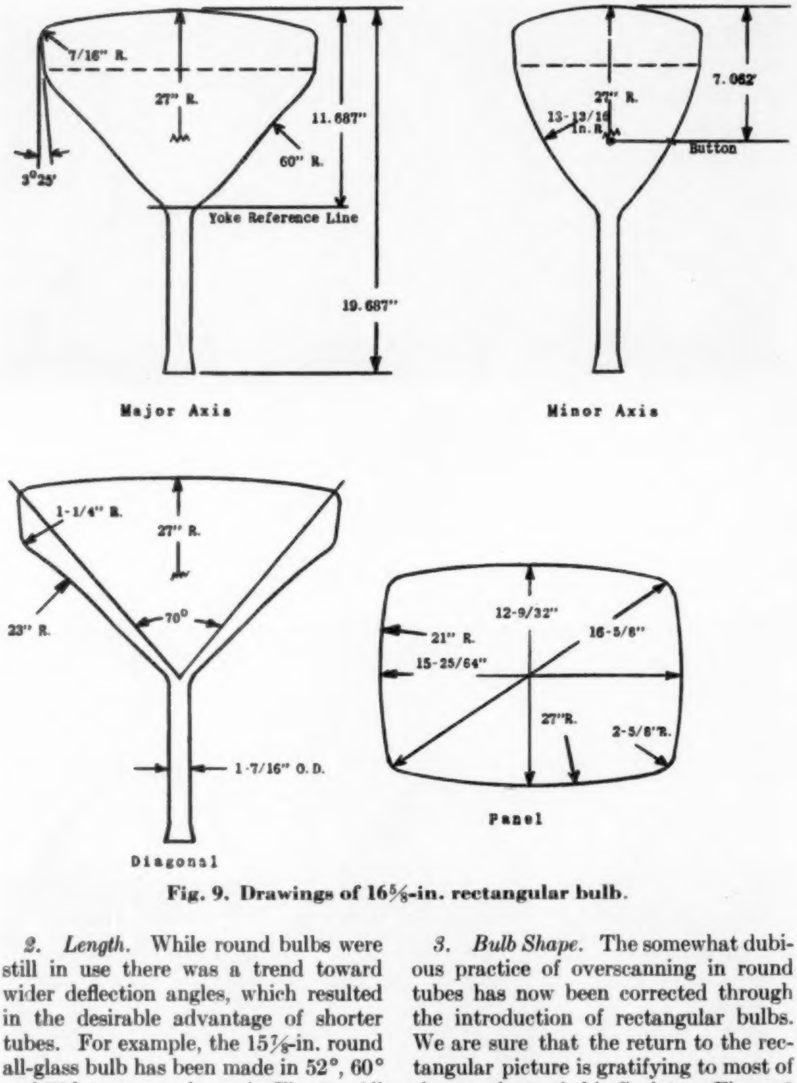

Fig. 9. Drawings of $16\frac{5}{8}$-in. rectangular bulb.

2. Length. While round bulbs were still in use there was a trend toward wider deflection angles, which resulted in the desirable advantage of shorter tubes. For example, the $15\frac{7}{8}$-in. round all-glass bulb has been made in 52°, 60° and 70° types, as shown in Fig. 7. All use the same panel, but different funnels. Shortening the bulb saves valuable cabinet space and this has become more important with the trend to larger sizes. At the time of writing, 70° is the commonly used deflection angle.

3. Bulb Shape. The somewhat dubious practice of overscanning in round tubes has now been corrected through the introduction of rectangular bulbs. We are sure that the return to the rectangular picture is gratifying to most of the members of this Society. Figure 8 shows the $13\frac{11}{16}$-in., $16\frac{5}{8}$-in. and $20\frac{3}{32}$-in. bulbs. At the time of writing, the $16\frac{5}{8}$-in. is a very popular type, although the demand for $20\frac{3}{32}$-in. is increasing rapidly.

4. Dimensional and Other Considera-

tions. The rapid rate of change has brought with it an engineering challenge of some magnitude and the problems of designing and building equipment of increasing size have resulted in considerable progress in the art of glass making. The demand for better and better glass quality has led to frequent revision of specifications and we should not here attempt to go into the six or seven pages of specifications that cover a single type, except to say that the glass quality and dimensional standards have steadily increased. Some of the conventions having to do with dimensions may be of interest. In Fig. 9 are outline drawings of the 16⅝-in. rectangular bulb, which show some of the important dimensions.

A practice of long standing in the lamp and tube industry is to rate the size of *bulbs* by use of a number which is the maximum outside diameter in eighths of an inch. Rectangular bulbs are rated by the diagonal dimension. For example, the 16⅝-in. bulb shown in Fig. 9 is a C–133. When the bulb is registered with the American Standards Assn. the size designation is prefixed with the letter "J." *Tube* sizes are also based on the maximum outside diameter, or diagonal, and are given in inches, to the nearest inch. Tubes are registered with the Radio and Television Manufacturers Assn., which assigns a title. For example, one of the tubes made from the 16⅝-in. bulb is the 17AP4. The "A" is a serial designation and the P4 describes the phosphor.

Future Developments

We believe the rectangular shape is here to stay. The $20\frac{3}{32}$-in. size is becoming very popular, but it does not appear to be the end and a rectangular bulb with a diagonal in the mid-20's is on the drawing board. The ultimate size will probably be limited by economic considerations and certainly by the size of the average door. How much wider the deflection angle will go is a matter that depends more upon circuitry and component considerations than on glass manufacturing. However, the larger sizes will bring pressure to shorten the bulb through use of wider angles.

To date virtually all the tubes manufactured have gone into new sets. It is the writer's opinion that there is a place in the home for a medium-sized picture, perhaps in the 14-in. range, and that in the future there will be a return to this size. Such a set might well be the "second" one in the home.

As of October, 1950, there is considerable interest in the use of nonglare finish on the face of tubes. This is a slight matte finish which diffuses reflections and thus lessens the annoyance due to recognition of various objects or light sources that are seen by specular reflection in the untreated tubes. Such a finish must be carefully controlled to strike the best compromise between reduction of specular reflection and loss of resolution and contrast.

A more recent solution to the problem of annoying specular reflections is the use of panels that have a cylindrical, rather than spherical surface, the axis of the cylinder being vertical. It is obvious, from simple geometry, that in most cases the seated viewer will not see reflections of lights and objects that are above his eye level and, also, that further protection can be realized by tilting the tube downward a few degrees. As a result, the room can be easily lighted to a desirable level without the annoyance of reflections. Also, there is no loss of resolution or contrast as is the case with tubes having a frosted finish. Demonstrations of operating tubes were held for tube and set makers in New York and Chicago in late October and the results were very striking.

Acknowledgment. A. E. Martin, Sylvania Electrical Products, Inc., very kindly furnished illustrations used in Figs. 3, 4 and 5.

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Discussion

Mr. Seeley: Would the author say a few words about glass tubes as compared with metallic tubes, with regard to the results that can be obtained and the cost of production?

Dr. Sheldon: I am not prepared to discuss the production costs. The performance is a matter of tubes, and I think that is a question that might more properly be answered by one of the tube people. So far as I know, there is no essential difference in the performance, once the tube is installed in the set. However, all-glass tubes have certain advantages as regards mounting in the set.

Anonymous: What is the minimum reflection on the face of a 20-in. tube—the minimum arc across the surface?

Dr. Sheldon: You mean the panel radius?

Anonymous: That is right.

Dr. Sheldon: The outside panel radius is 40 in.

Anonymous: What is the chord across the curved surface of the face of the tube?

Dr. Sheldon: Across the maximum diagonal? That is about 1½-in. less than that (20 in.), approximately. That takes care of the thickness of the glass and the radius.

ABSTRACT

Stereo-Television in Remote Control

By H. R. Johnston, C. A. Hermanson, and H. L. Hull

The study of the possibilities of using three-dimensional television in conjunction with remotely controlled electric manipulators is part of a long-range development program being undertaken by the Remote Control Engineering Division of the Argonne National Laboratory.

Manipulation of objects in three dimensional space requires that depth perception be incorporated into any scheme used to view and control the means of manipulation. It is not sufficient to use ordinary two-dimensional television for this purpose since the ability to judge depth is almost entirely lacking.

A standard Du Mont television pickup chain was employed in the development of stereo-television. The stereoscopic pair of images are placed side by side by a twin lens system onto the photocathode of the television camera tube. The images occupy the same space on the photocathode as a single image in standard two-dimensional television and they are transmitted simultaneously. At the receiving end of the stereo-television system, the two images appear side by side on the face of a standard kinescope or television picture tube.

Two polarizing filters whose axes of polarization are at right angles to each other are placed immediately in front of the images on the cathode-ray tube. An observer wears a pair of polarizing spectacles so oriented that the right eye is permitted to see only the right-eye image and the left eye sees only the left-eye image.

A second method used to view the three-dimensional television pictures makes use of two television picture tubes. These tubes are arranged at right angles to each other and a semitransparent mirror is placed so that it is at 45° with both tubes. Crossed polarizing filters are placed in front of each picture tube and the observer wears crossed polarizing spectacles. The observer is enabled to see the three-dimensional image by observing one image by transmission through the semitransparent mirror and the second image by reflection.

To test adequately the possibilities of the stereo-television system as a means of seeing objects in three-dimensional space, two mechanical Master-Slave manipulators were arranged so that the operator sat with his back to a wall, behind which the slave hands and the stereo-television were located. The operator faced the stereo receiver and saw a three-dimensional image of the manipulator "slave" hands and objects in the work area, while with his hands in the "master" controls he manipulated objects in the field of view. After a few

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Abstract by Pierre Mertz of a paper presented on September 26, 1950, at the National Electronics Conference at Chicago, Ill., (in which the SMPTE Central Section participated), by H. R. Johnston, C. A. Hermanson and H. L. Hull, Argonne National Laboratory, P.O. Box 5207, Chicago 80. The complete paper was published in *Electrical Engineering* for December, 1950, and will also be published in *Proceedings of the National Electronics Conference,* vol. 6 (for 1950).

minutes of indoctrination any person with normal vision can be taught to see and manipulate the objects in view from a remote distance. In another setup, an electrically operated manipulator was made to perform miscellaneous feats of lifting objects and pouring liquids from one beaker to another, while the operator controlled its movements from another room over 50 ft away.

The present system of stereo-television using one camera pickup tube, gives a stereo picture which has an aspect ratio of three high and two wide. This may be undesirable for use in any permanent installation. In addition, the field of view is restricted, and the resolution is adversely affected.

A more desirable system would consist of the use of two television camera pickup tubes arranged side by side in a horizontal direction. The left pickup tube would supply a left-eye view to one of the receiving tubes of the dual viewer and the right pickup tube would supply the video signal for the second receiving tube.

ABSTRACT

The Orthogam Amplifier

By C. L. Townsend and E. D. Goodale

FOR SOME TIME it has been known that iconoscope film pickup tubes[1,2] do not produce video voltages ideally suited for reproduction by a normal kinescope unless gradient correction is applied. A re-evaluation of the transfer characteristic required in the television transmission system for optimum picture quality was undertaken, to include conditions actually encountered in normal commercial broadcast operation.

A series of slides was produced, each having an "average gray" background (density about 1.2) and, centered in that area, a rectangular "window." Each slide was made with a different window density, to cover the range normally encountered in practice. The slides were projected in succession, and in such a way that the same portion of the mosaic was used for each window. Oscilloscope readings of the voltages so generated showed a reasonably linear relationship with window density.

To determine the characteristic which is actually obtained in the existing recording-reproducing system, the "window" test was again used. A video voltage, representing the window and an appropriate background, was fed to the recording system. The amplitude of the voltage of the window proper could be precisely controlled to produce any value within the normal recording range, plus some excess into overload values, if desired. A recording was made of this signal, and the film processed normally. That film was then reproduced on an iconoscope system, and the output voltage values noted on an oscilloscope.

Abstract by Clyde R. Keith of a paper by C. L. Townsend and E. D. Goodale, Engineering Dept., National Broadcasting Co., Inc., RCA Bldg., Radio City, New York 20, published in *RCA Review*, vol. 9, no. 3, pp. 399–410, Sept. 1950.

The resulting plot is shown in Fig. A [Fig. 3 in original paper], and includes a wider range than is normally used. A serious compression of white-range voltages is present. All transfer characteristics of the intermediate recording and reproduction steps also were plotted with significant information produced at each point. Exposure and processing methods were altered in an effort to reduce the undesirable effects shown in Fig. A, but the general characteristic remained.

An analysis of Fig. A indicates that some nonlinear compensation is needed for both direct film and kinescope recording reproduction. The two cases differ as to amount required, but are otherwise generally similar. Both are simple curves, and compensation should be feasible.

Many times in the past "gamma correction" amplifiers have been built which had variously shaped transfer characteristics. Most of these actually compressed one part of the characteristic in order to get a relative expansion of another. Figure A indicates that the "black" half of the characteristic should not be altered, but rather an expansion in the "white" range is required. No *gradient* change should be permitted in the near-black signals, even though their relative amplitude is reduced to permit white expansion.

With the above requirements in mind, the Model "A" orthogam amplifier was designed with two parallel amplifiers, as indicated in Fig. B [Fig. 4 in original

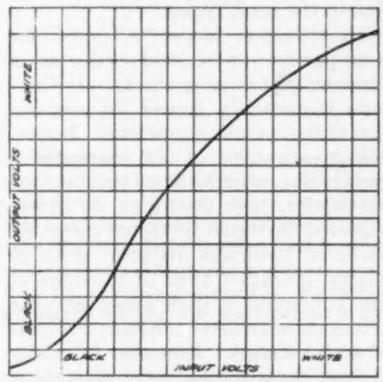

Fig A. Volts input to kinescope recording versus volts output from film reproducer.

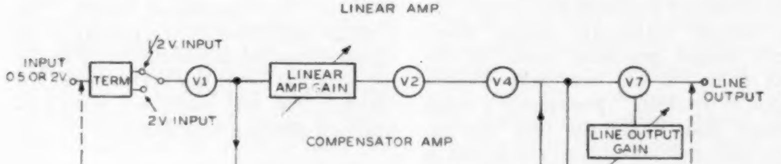

Fig. B. Block diagram of Model "B" orthogam amplifier.

paper]. The upper branch path provides a completely linear output voltage, to which the lower branch adds expanded white voltages. Large video voltages can be fed to V5, and its bias can be controlled to allow only the highlight tips of those voltages to be passed by the tube. Thus both amount and gradient of the correction can be controlled, without causing nonlinear operation in the black region.

Six orthogam Model "A" amplifiers were put into operational service as an extended performance check. "In-Out" tests immediately gained the cooperation of the operating personnel. Noticeable improvement in film transmission quality was commented on by observers not familiar with the tests. As an unexpected dividend in many cases the effect of flare was reduced, since in normal operation most of it occurs at low amplitude in dark areas, and the orthogam reduces the relative amplitude of such voltages. However, it shortly became apparent that some changes in the method were required. Operating crews found the units were "wild"—that is, they made video level riding difficult. This was found to be due to the fact that once a correct gradient was chosen for the normal maximum voltage level, much steeper gradients existed above that point, in the nominally unused region of overload. Frequently a video voltage peak would rise into that region and the additional amplification there would drive it far higher than it would otherwise have gone. Subsequent reduction of system gain corrected the matter, but only after a troublesome transition period. With close attention during rehearsal, and constant vigilance during broadcast, these effects could be acceptably minimized, but final judgment was that the Model "A" was not an operationally desirable tool.

Based on the above results, a new attack on the problem was made. Using the same basic philosophy of correction, it was decided that the major additional requirement was that the top desired gradient must be the greatest actually encountered in the system under operating conditions. Thus, instead of a continuously rising gradient in the overload-voltage region, the new orthogam must be linear at the steepest desired slope. This objective has been achieved in the Model "B" orthogam amplifier. [A circuit schematic and description are given in the original paper.]

Several NBC film studios now have been equipped with Model "B" units, and considerable operational experience indicates that the gainriding difficulty experienced with the "A" model has been largely overcome and substantial improvement provided in the transfer characteristic of the over-all system. This is evidenced in the viewed picture by a reduction in the chalkiness of faces and an improvement in the separation between other white and near-white portions of the reproduced image. The average brightness of the picture is reduced somewhat due to the fact that the a-c axis has been pushed towards the blacks. The end result is a more natural and pleasing reproduction.

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Diffuse and Collimated T-Numbers

A Review and Description of New Equipment

By Allen E. Murray

The SMPTE Subcommittee on Lens Calibration has formally recognized, through incorporation in its report, two methods of lens calibration. While they reach equivalent results and will calibrate lenses identically when properly safeguarded, each has its own shortcomings and advantages, which are not commonly recognized. To dispel the evident misunderstandings about these two methods, they are compared and the reasons are indicated for the method chosen. New equipment designed by Bausch & Lomb Optical Co. for lens calibration based on the diffuse method is described briefly.

FROM THE INTERDEPENDENCE of physical phenomena it follows that a given quantity can be measured in more than one way. The more fundamental it is, the larger is the number of its interrelationships and the larger the number of methods available for its evaluation. In the realm of pure physics this principle is put to use in assuring consistency of theories and the correctness as well as the limits of accuracy of fundamental constants. On the engineering level it assures, in addition, the solution of virtually any problem that may be raised, since it provides alternative procedures for finding the solutions, as well as checks on their correctness.

Presented on October 19, 1950, at the Society's Convention at Lake Placid, N.Y., by Allen E. Murray, Scientific Bureau, Bausch & Lomb Optical Co., Rochester 2, N.Y.

It is interesting to note that there is also a complementary principle at work: the principle of uniqueness of experimental arrangements and implications. This requires that the results obtained from given experimental equipment be specific to that equipment and issue only from the principles it employs. The distinctions thereby created may in many cases be without a difference, but the possibility of alternative methods of accomplishing things implies that the things done are not identical in detail.

These observations are prompted by the recent history of photometric lens calibration. This problem reduces, in essence, to the measurement of the illuminance in the image plane of a lens under such conditions that the transmittance and relative aperture are evaluated together. This requires, in principle, that the illuminance at a particular stop be compared with the

illuminance produced by an ideal lens or its equivalent at a similar stop. Within the limitations of the general method there is a large number of procedures capable of meeting the requirements of accuracy and obedience to essential physical principles. These procedures are not all equally reliable or sound, and each measures the illuminance under a different set of circumstances, i.e., measures a quantity which, though related, is not always the one wanted.

All these considerations were in the collective mind of the Society's Subcommittee when it prepared its report[1] and, in Appendix II, discussed two general experimental procedures whereby the T-number could be evaluated. The Subcommittee, however, understandably failed to point out that of all physical procedures, the photometric are among the most treacherous, in that even when the principles are correctly applied, it is disconcertingly easy to commit some simple error of omission, failure to eliminate every last trace of stray light for instance, vitiating the whole procedure. The extent to which extremely careful attention must be paid to every safeguard in photometric practice is not realized by those unfamiliar with photometry, and as a result many proposals of unequal merit have been published from time to time.

The Subcommittee also failed, and equally understandably, to point out that the two methods, being different *ab initio,* must evaluate different physical quantities, and moreover each must have its own set of shortcomings and advantages.

The Subcommittee was following historical precedent when it chose to describe the collimated and the diffuse source methods, for the published procedures have fallen naturally into the same two classes. These published methods are included here for their historical interest, and are further classified according to whether the light is sent in the normal or counter direction through the lens:

I. Collimated Source

Normal	*Counter*
Silvertooth[2]	Odencrants[5]
Daily[3]	Hrdlicka[6]
Townsley[4]	

II. Diffuse Source

Normal	*Counter*
Lambert[7]	Berlant[14]
McRae[8]	Murray[15]
Moffitt[9]	
Clarke & Laube[10]	
Sachtleben[11]	
Gardner[12]	
Back[13]	

A balance sheet of the several advantages and disadvantages in principle and practice can be drawn up without difficulty. After noting that the collimated methods in effect evaluate a quantity proportional to the diameter of the entrance pupil of the objective, while the diffuse methods evaluate the flux on the image side of the lens, an unimportant distinction for most purposes, the two methods can be compared on their merits as procedures yielding the T-number defined by the Subcommittee.

I. Collimated Source

Advantages

1. Focusing unnecessary
2. Lens always correctly focused
3. Little power required in source

Shortcomings

1. Knowledge of equivalent focal length of lens essential
2. Requires different set of apertures for each focal length or calibrating means such as Townsley's[4]
3. Theory more complex
4. Indirect measurement of T-number
5. Uniformity of collimated beam is troublesome to ensure; the effect of beam spread is difficult to evaluate
6. Not directly adaptable to finite magnifications
7. Entrance pupil diameter limited by collimator lens

II. Diffuse Source

Advantages

1. Focal length knowledge unnecessary
2. Adaptable to any magnification (with focal length known)
3. More fundamental and thus simpler in principle
4. Maximum lens aperture unlimited

Shortcomings

1. Focusing essential
2. Attainment of uniform source quite difficult
3. Light losses large—high sensitivity in detector or great power in source required

The criticisms are readily seen to be unequal in weight, numbers 3 and 4 under the collimated source being minor objections in the theory, while 2 and 5 can be overcome by careful engineering. The most serious of these shortcomings are perhaps 6 and 7, and in this order. It is no trick to measure the equivalent focal length accurately enough (1), but the limitations to lenses of a given diameter and always at a fixed magnification are real handicaps. The collimated source method demands that the collimator lens always be larger than the entrance pupil of the lens being tested, and this requires costly lenses in larger sizes. The author knows of no simple way of adapting this method to finite magnifications.

The advantages of this method are all substantial: to have the lens under test automatically and securely focused undeniably creates confidence, and the convenience of a light source whose power requirements are small is not to be denied.

Except for the first, the shortcomings of the diffuse method are serious enough to demand the most careful engineering. Focusing is easy; it can be done by autocollimation or by the use of a telescope. It demands considerable engineering effort, however, to ensure an extensive diffuse source whose uniformity is sufficient to meet the requirements, and in addition sound design to attain useful sensitivity with reasonable power input into the lamphouse.

Numerous methods of assuring uniformity with diffusion have been proposed. Perhaps the best is the one proposed in the Subcommittee Report, using a sheet of direct-light shielded ground glass to cover the aperture in a matte white box. Even at best, however, these lamphouses must be large, since it is necessary that the T-stop equivalent solid angle be filled with flux at all values. Fortunately the measurements are independent of the source distance when the incident cone is filled.

The advantages of this method counterbalance the disadvantages. It is clear that adaptability to all magnifications and no restrictions on lens aperture together make up a strong argument in its favor.

These considerations seemed to us to be so cogent that when we designed the equipment to conform with the Subcommittee recommendations, we chose the more fundamental diffuse source procedure. Our equipment was specified to be null reading, in order to remove all questions of photocell response linearity and as nearly as possible to compare unknown with standard aperture simultaneously, in order to avoid any possibility of faulty mechanical or electrical memory.

Both objectives have been realized (Fig. 1) by providing two apertures into the integrating box which illuminates the detector photocell. These apertures are alternately opened and closed thirteen times per second, so that the same total area is free to the lamphouse at all times—first, all of one aperture, and as this closes, the other opens synchronously to completion. Thus when the flux incident on the two apertures is the same, there is a constant light level within the box. When, however, one aperture is blocked completely, the light level varies as the size of the uncovered aperture, sinusoidally in this equipment.

The two functions of the phototube and the electronic circuit are then to detect the state of light balance and to measure the degree of unbalance. Figure 2 illustrates the principle of measurement, while Fig. 3 shows the schematic electric circuit.

It is clear that balance comes about electrically when the amplitudes of the 13-cycle signals arising from the two apertures are equal, for then, since they are phased 180° apart, the resultant signal is constant.

The dominant aperture in the general case will phase the light signal. To determine which aperture this is and to produce a deflection at light balance, an auxiliary bipolar generator is synchronized with one aperture, and the measuring circuit designed to evaluate the sum of the light and generator signals. By adjusting the circuit properly, the indicator can be placed at midscale with only the alternating component of the generator effective so that deflections to

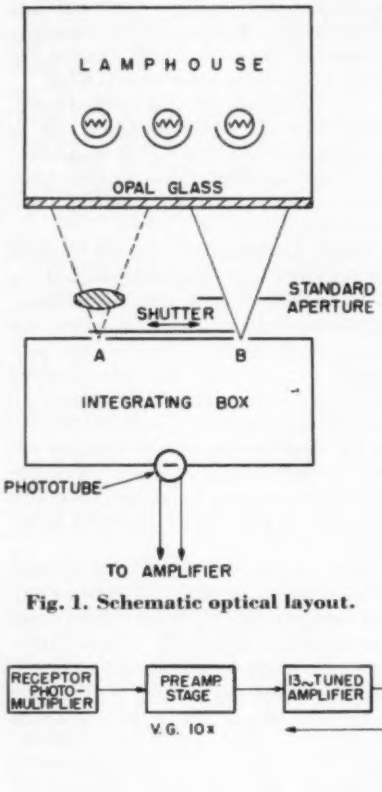

Fig. 1. Schematic optical layout.

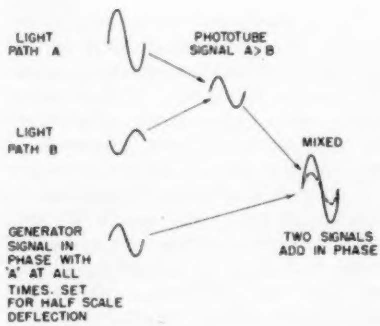

Fig. 2. Principle of measurement.

When A > B resultant mixed signal is > half scale

When A = B resultant mixed signal is half scale

When A < B resultant mixed signal is < half scale

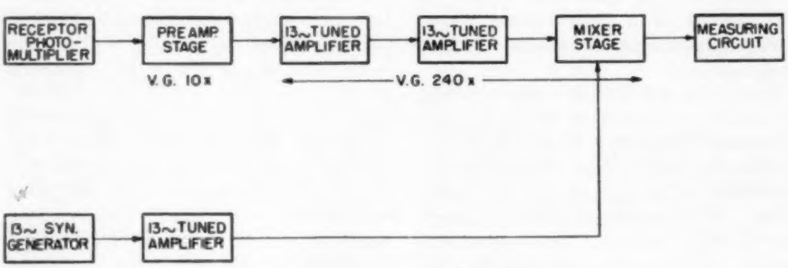

Fig. 3. Schematic electrical circuit.

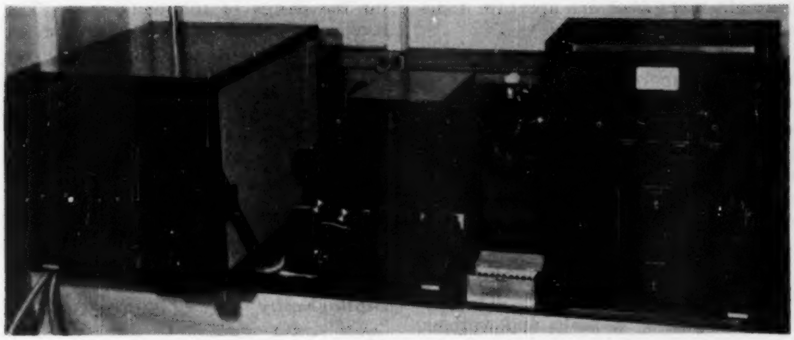

Fig. 4. General view of equipment.

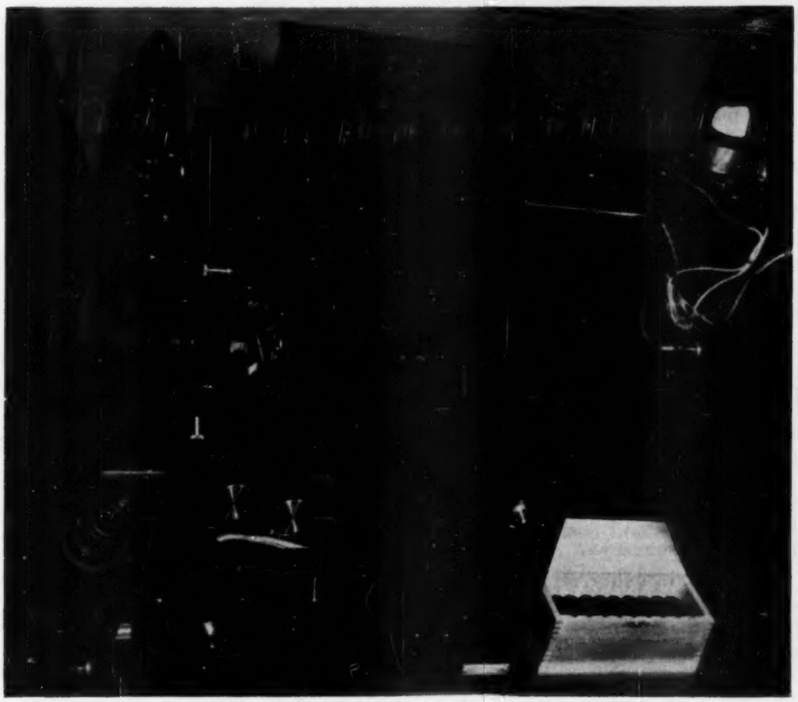

Fig. 5. Lens Mount and Standard Aperture Turret.

the right mean that one aperture dominates, and to the left, the other.

Moreover, by the use of the auxiliary calibrating apertures it is possible to calibrate the meter in terms of T-numbers between each two consecutive full stops, and thus interpolate between stops for measurement or calibration purposes. This eliminates the need for neutral density filters.

A general view of the equipment is contained in Fig. 4, and Fig. 5 shows the front of the integrating box. The lens standard carries a scale and vernier, which make it useful for measurement at finite conjugates. This scale is indispensable for maintaining or checking on the calibrations and sensitivity.

The T-stops are defined by apertures placed a fixed distance from the integrating box aperture and carried on a turret plate. These are duplicated in a loose set of apertures fitting into an adapter in the lens standard.

The illumination at present is provided by a large lamphouse containing three 500-w projection lamps. It is coated white inside, and the front face is a large sheet of flashed opal glass. The uniformity of luminance of the face just meets the specifications contained in the Subcommittee Report. Some other arrangement doubtless would be safer in future equipments.

This particular calibration unit has proved to be quite handy in practice, more than adequately sensitive with the focal plane apertures for the 35-mm and 8-mm frames, with the 1P22 photomultiplier tube and three accelerating potentials, and self-contained in that it calibrates itself with the help of the auxiliary apertures and basic instrumental dimensions.

The reproducibility of measurement at all stops is of the order of less than 1%, and the accuracy certainly well within the allowed ±7% in illuminance.

Acknowledgments: An enterprise such as this is the result of group effort, and therefore it is necessary to distribute the credit for the design of this equipment. The mechanical design was ably carried out by R. Filsinger under the direction of O. Boughton, while the electronic circuit is the result of the joint efforts of K. H. Bloss and A. A. Shurkus, assisted by W. Ehlers. The mechanical assembly was under the direction of W. Guenther. The author also wishes to acknowledge the help given in conversations with his colleagues, in particular Dr. K. Pestrecov and G. C. Wooters.

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Discussion

M. C. Townsley: Is your instrument primarily intended for calibrating apertures or measuring apertures?

Mr. Murray: Actually, of course, the equipment does both. It was designed primarily to calibrate, but we picked up facilities here and there in the course of the design of the equipment. We are more than pleased that it will serve both functions.

Mr. Townsley: It looked from the way it was laid out that it could do both and probably do them quite well.

Mr. Murray: We have felt from the very beginning that calibration alone would not be sufficient. We wanted to be able from our own equipment, independently of any other, or from fundamental geometry and mechanical construction, to determine that the calibration is done properly.

Mr. Townsley: In calibration, I am thinking of starting with an unknown lens and marking a set of apertures in T-stops.

Mr. Murray: We can do that very well for the standard apertures on the turret plate. Their distance from the obscuring aperture in the lamphouse is known to around two tenths of one per cent. The diameter of each aperture has been measured along at least four meridians, so that we know they are circular. Their edges have been specially treated to cut down reflection. We put in what refinements we could see.

Mr. Townsley: I rather hope for the future of the T-stop system that you will do a great deal of original calibration on customer lenses on that system—actually mark them in T-stops.

Mr. Murray: I am authorized to say that this equipment will be used also for customer lens calibration. Our sales department has just let me know that we are ready to undertake this sort of work. You personally might be interested to know that we have had the opportunity to look over some of your lenses, and we are very pleased to note that we agree very closely.

This paper was prompted by some question as to whether one method is better than another. We must say "no." There is no visible justification for setting up a standard around one particular device or method. Any equipment is satisfactory as long as it conforms to physical principles and the requirements of sound engineering.

The Differential Carbon-Feed System for Projection Arc Lamps

By Arthur J. Hatch

There is a growing recognition of the fact that to obtain constant screen color and light intensity, the position of the positive carbon must be maintained automatically in relation to the projection lamphouse optical system. In the development and application of such a control feature, the requirements of carbon-feed systems have been reviewed. The differential carbon-feed system seems to meet these requirements, and considerations pertaining to the application of the differential feed system with automatic positioning to an angular trim burner will be related.

The challenge offered by present large screens, and the demand for higher picture brilliancies have led to the wide adoption of high-speed projection lamphouse optics, and carbons with higher intrinsic brilliancy.

With these the allowable tolerance in carbon crater position has been reduced by the use of the higher-speed lamphouse optics, while the difficulty of maintaining the arc crater at a given position has been increased by the high brightness carbons with their higher burning rates. These higher burning rates are unfortunately accompanied by greater fluctuations of burning rate with small current changes. These factors have made it desirable to incorporate automatic means in the carbon feed to maintain the position of the positive crater accurately to the lamphouse optical system.

This problem of providing automatic positioning to the positive crater of high-intensity projection arc lamps has necessitated a review of the requirements for carbon feeds, as such a positioning control cannot be conveniently or effectively inserted into the type of feed mechanisms in general use at present. Accordingly, to utilize an automatic positioning device it has been necessary to develop a new carbon-feed system.

To anyone not especially acquainted with operation or design of projection arc lamps, the feeding of the carbons would seem a very simple matter that could readily be solved by merely arranging a motor drive to both carbons. However, as it is with so many other seemingly simple problems, this subject is not altogether simple when the complete requirements are known.

Presented on April 27, 1950, at the Society's Convention at Chicago, Ill., by Arthur J. Hatch, The Strong Electric Corp., 87 City Park Ave., Toledo 2, Ohio.

Requirements of Carbon-Feed System

We find that the principal end results desired are uniform and constant intensity of screen illumination with constant color temperature. These results should be obtained through a carbon-feed system that has simple control adjustments and which is capable of self-compensation for changes in the variables, without attention from the projectionist.

Upon examining these requirements for a feed system, we find that the major electrical controlling factor necessary to obtain constant screen illumination, with a given carbon trim, is constant arc amperage.[1] With proper arc circuit ballast, the arc amperage will assume a value such that the sum of the positive and negative carbon-burning rates, at that arc current, equals the sum of the positive and negative feed rates. Then assuming for the moment that the carbon-burning rates are constant for a given current, it will be readily seen that a constant total feed rate will provide most even illumination.

Therefore, a very simple carbon-feed mechanism could be constructed which would advance the relative positions of the carbon holders one to the other at the constant rate necessary to maintain the desired current.

The negative carbon could stand still and the positive carbon could be advanced at a rate equal to the total burning rate of both carbons; or the positive could stand still and the negative could advance at the total rate. Any number of positive and negative feed ratios could be used as long as the combined feed added to the figure desired for total feed.

This simple feed, however, would not take into account the fact that to utilize the illumination from the carbon arc for projection, the positive crater must be kept at the exact entrance focal position of the lamphouse optical system. It is, therefore, necessary to make provision to divide the total feed into positive and negative feeds, in a proportion exactly equal to the positive and negative burning rates at the particular current desired, in order to maintain the position of the positive crater to the optical system.

This division of the total feed into its components needs to be flexible, unless the lamp is to be burned at a single current, as the ratio between positive and negative burning rates varies considerably through the current range of the carbons.[2]

The operation of this ratio-fixing control should not affect the sum total feed rate of the positive and negative carbons. For this reason a ratio-changing system is necessary in which, if the negative feed is slowed down, the positive feed is increased simultaneously so that total carbon feed and constant current are maintained.

An Ideal Feed System

From the foregoing it is easy to draw a conclusion that an ideal feed system would be one in which one control determined the total feed and the other control determined the ratio between positive and negative feeds. With a system of this type, the total feed control could be set for the desired amperage and the ratio control adjusted until the feed ratio matched the burning ratio. This second adjustment would not affect the feed-control setting.

Thus, for example, with a 7-mm negative and 8-mm positive copper-coated high-intensity trim the total burning rate for both carbons at 70 amp is approximately 20 in./hr. The current selector would be set to produce this total rate of feed. Then the ratio control would be adjusted, until the position of the burning tip of the positive carbon in relation to the optical system was correct and its relative movement reduced to zero. It thus might be found necessary to adjust the ratio control

setting so that the negative feeds 4 in./hr, and the positive, 16 in./hr, or the negative might be fed 4¼ in./hr, and the positive, 15¾ in./hr. In either case the total feed would remain at 20 in./hr. and the arc current at 70 amp.

This ideal feed system is analogous to that of a mechanical differential system, a common type of which is found in the rear drive of automobiles. Here the speed of the torque tube drive shaft is analogous to the total feed of both carbons. The sum of the drive of the two rear axles is a constant for constant-torque tube drive and the ratio between axles can be varied by restraining one wheel in which case the other wheel turns faster.

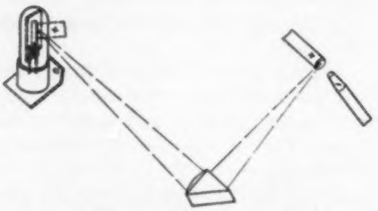

Fig. 1. Carbon position-detecting optical system showing prism lens and bimetallic switch.

A practical embodiment of this ideal feeding system can be realized with the use of a two-motor drive. One motor, which is the feed motor, drives both carbons through a differential gear drive. The second, or rate-control motor, is connected preferably in the negative drive. The resultant difference in drive between the feed motor and the rate-control motor is transmitted to the positive carbon feed. Gear ratios are chosen so that the resultant total feed of both carbons is, at all ratios, a constant as determined by the speed of the main drive.

Fig. 2. General view of differential feed burner from operating side showing positive and negative feeds and the single adjustment control.

Need for Automatic Positioning

This feeding system and almost all present arc feeding systems make an assumption that there will be little or no variation in arc gap length, carbon-burning rate or power supply voltage. However, in practical experience these ideal conditions are seldom satisfied.

Variations in carbon-burning rates and ratios at a given current, of course, directly reflect a change of position of the arc with respect to the lamphouse optical system. Arc-gap lengths at identical currents and even with constant applied arc voltage will vary from trim to trim and even within a trim. With constant arc current, the dependent variable that compensates for variation in arc supply voltage is the arc-gap length. As the positive carbon has the highest burning rate (being approximately 2 to 8 times that of the negative carbon), the major adjustment in position for variations in arc-gap length occurs in the position of the positive carbon. Thus, variations of arc voltage or gap length directly affect the position of the positive crater in relation to the optical system.

Therefore, to adopt the ideal carbon-feed system to these practical considerations, there must be introduced an element that will maintain the positive crater at the optical focal point regardless of variation in arc gap or burning rate.

It is, therefore, practical to introduce a carbon crater position-detecting and ratio control-actuating mechanism into this system to accomplish this end. The

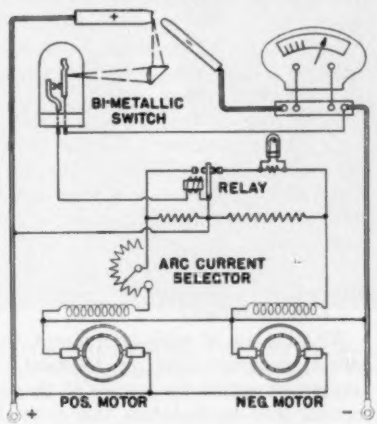

Fig. 3. Simplified arc control circuit diagram.

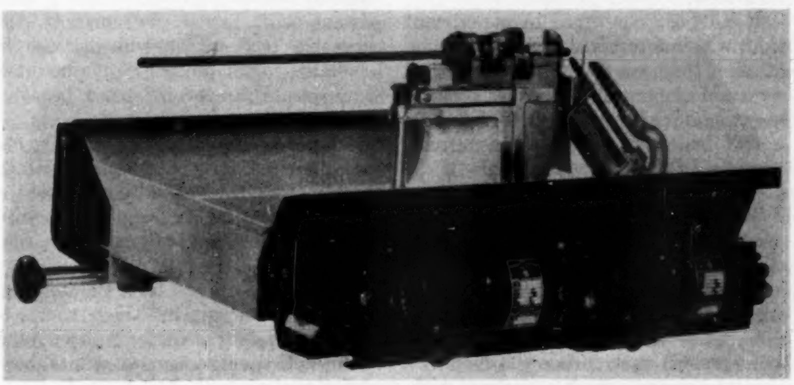

Fig. 4. General view of burner from nonoperating side showing motors and bimetallic switch behind left motor.

bimetallic element with its ruggedness and simplicity seems to be most practical for this position detector.[3]

This bimetal switch is simply arranged to shunt out a series resistance in the ratio-motor field circuit. With all resistance shunted out, the ratio motor runs at a speed such that the negative carbon is fed at a rate below its burning rate, and the positive is fed at a rate above its burning rate. When the resistance is inserted by action of the bimetal switch, the negative is fed at a rate above, and the positive at a rate below its burning rate.

Total rate of feed at any selected amperage is obtained from the main-drive motor, and the position of the positive carbon is accurately maintained with the controlled variation of the ratio motor.

Angle-Trim Lamp-Feed Considerations

With the use of angle-trim lamps, the general considerations for constant illumination remain the same with the exception that to maintain this even illumination, the feed rate of the negative has to be corrected for its angular direction before it can be added to the positive to obtain the value for combined total feed.

It has been confirmed by experiment that, within a reasonable limit of movement, if the positive carbon is underfed a certain amount, X, an overfeed of the negative equal in amount to X cosine α will maintain constant arc current, where α is the depression angle of the negative in relation to the positive.

Taking advantage of the uniform and predictable speed characteristics of the d-c shunt motor, it is possible to design an electrical differential motor feed circuit whereby the use of the mechanical differential is eliminated. With this arrangement, each carbon is driven by a separate motor. Such a system, without an automatic position-control switch, would contain two controls, each consisting of two rheostats connected in mechanical tandem. Each of the rheostats in the total feed-rate control would be connected in the field circuit of its respective motor, and the resistance values arranged so that the carbon-feed speeds were changed approximately in their correct values throughout the entire current range of the carbons.

The ratio-control rheostats would be connected in the two-motor field circuits in such a manner that as the ratio control was advanced, the positive feed motor would be slowed and the negative feed motor would be speeded the correct amount to maintain the same current in the lamphouse.

For automatic positioning, the bimetallic element would be arranged to shunt in and out portions of this ratio-control rheostat. The general optical arrangement for projecting the energy image of the positive carbon and flame to the bimetallic switch is shown in Fig. 1. The 90° prism with a lens ground in one face is used to direct the side view of the arc to the glass-enclosed bimetallic switch.

Single-Feed Control

It is possible to obtain d-c shunt motors with speed characteristics such that as the arc voltage is raised, consistent with higher arc currents, the negative feed motor will increase in speed approximately the right amount to compensate for the increased negative burning rate.

This fact, in conjunction with the use of a fairly large speed differential on both motors, controlled by means of the position-sensitive device, has enabled considerable simplification of the control circuit.

The net result has been the development of a circuit in which complete control of both carbon feeds throughout their entire amperage range has been accomplished with but a single lamphouse feed-control adjustment. This control is in the form of a single rheo-

Fig. 5. (a) The arc burning with no air supplied from jet showing the characteristic long-tail flame reaching toward the optical system.

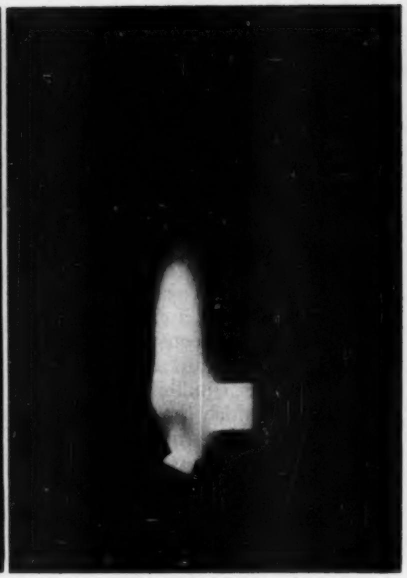

Fig. 5. (b) The burning arc showing how the application of air from the jet shortens and redirects the flame.

stat which is provided with a pointer and a scale indicating arc amperages. The general arrangement of components of a burner incorporating this two-motor, single-control feed system as viewed from the operating side is shown in Fig. 2. A simplified wiring diagram of this system is shown in Fig. 3.

The rheostat is connected in the positive feed motor field circuit and has a value sufficient to control the feed of the positive carbon through a range of from 14 to 32 in./hr.

The bimetallic switch is connected in such a manner that in its open position, a resistor is inserted in the positive field, and a resistance is shunted out in the negative field, thus speeding the positive and simultaneously slowing the negative. When the bimetallic switch is closed by reason of the positive carbon position being slightly too near the optical system, the resistor in the positive field circuit is shunted, and the resistor is simultaneously inserted in the negative field circuit, thus slowing the positive and speeding the negative.

The positive motor will change speed sufficiently with this cycling to change the feed rate by approximately 4 in./hr from fast to slow rate. With the negative carbon being depressed at an angle of 52°, its feed rate is arranged to change 4 × cos 52°, or approximately 2.5 in./hr from fast to slow.

When the arc current selector rheostat is set at the desired current, the positive motor assumes a speed, such that the average speed between high-

and low-cycle speeds is equal to the average burning rate of the positive carbon at the selected current.

If the arc current at a particular instant is slightly less than the selected current, the positive burning rate will be slightly lower than the average positive feed rate. Consequently, the arc position-control switch will remain in the low-speed positive feed position longer at a time, than in the high-speed positive feed position. This will cause the negative to be fed at a greater average rate than it is being consumed, thereby shortening the arc gap, and raising the current, until an equilibrium condition is reached, at which the average negative and positive burning rates equal the average feed rates. This will be realized at approximately a 50% division of time on high and low speeds.

If the arc current, and consequently the positive burning rate is higher than the selected rate, the arc position-control switch will remain in the high-speed position longer at a time than in the low-speed position. This will cause the negative to be fed at a lower than average rate, thereby lengthening the arc gap until equilibrium is reached.

Slow changes in power supply voltage are compensated for by the automatic resulting change in arc-gap length, but with the continual maintenance of the positive crater at the required position.

Miscellaneous Features

Secondary considerations in connection with the realization of the two-motor automatic positioning drive include the provision of centrifugal fans on each of the motors (see Fig. 4). These fans exhaust into the burner base enclosure from where the air is directed up through the rotating positive feed head, and against the negative feed head, thereby keeping these parts at low operating temperatures.

Immediately above and parallel to the negative carbon is located a jet tube which directs a stream of air at the arc tail flame immediately above the crater.

This device has several useful functions in that it shortens and redirects the tail flame away from the reflector, as shown in Fig. 5. The white ash product of combustion of the arc is blown away from the reflector thereby eliminating deposit on the reflector and the consequent breakage caused by heat differentials.

Another benefit derived from the air jet is that it supplies enough additional air to the vicinity of the arc that upon striking the arc, the soot particles are consumed instead of being released to the reflector surface, or lamp-house interior.

Finally, the air jet causes the blending of the negative and positive flames and results in excellent stabilization of the arc without the use of an auxiliary magnetic field. Thus, with the embodiment of the differential concept of carbon feed which was developed for the purpose of obtaining uniform feed in conjunction with automatic positioning of the positive crater, it is possible to stabilize the burning of the arc and keep the products of combustion from the lamphouse optical system.

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Bibliography on High-Speed Photography

Including Schlieren and Cathode-Ray Oscillograph Photography

Contents

This bibliography was compiled by Miss Elsie Garvin, Librarian, Research Library, Eastman Kodak Co., Rochester, N.Y., and was recommended for publication in the *Journal* by the Society's High-Speed Photography Committee. Those who reviewed the 600 items suggested that they be arranged by subject and that certain entries be expanded by annotation. John H. Waddell, Chairman of the Committee, undertook the job of classification; many more items were added, dating up to July, 1950; and manuscript was released on December 7, 1950, for publication.

The Society has previously published two reprint volumes on high-speed photography and this bibliography will be the last item in Vol. 3 which will include also those papers on the subject which appeared in the *Journal* during 1950.

To expand its usefulness the third volume will include a cumulative table of contents showing the titles and authors of all papers in Vols. 1 through 3. It will cover all articles on the subject which appeared in the *Journal* beginning with the special issue, Part II of the March, 1949, *Journal*.

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VII. X-RAY

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A and B Windings of 16-Mm Raw-Stock Film With Perforations Along One Edge

The Proposed American Standard for Winding of 16-Mm Sound Film, was published as a first draft in the September, 1949, Journal. While that was the first time that winding 16-mm sound film had been proposed for adoption as an American Standard, the proposals were practices already followed by the film manufacturers for a number of years. It should also be noted that, in 1941, the Society recognized the method of designating the two types of windings by publishing a Society recommendation, and that recommendation was substantially repeated in the first draft for this proposed standard.

As a result of publishing the first draft, comments were received which indicated ambiguity in the original wording; therefore, a second draft was prepared by the 16-Mm and 8-Mm Committee in January, 1950. That draft was sent to ballot of the 16-Mm and 8-Mm Committee in April, 1950. Only minor editorial comments were received and, therefore, this proposal is again being published for 90-day trial and comment (see page opposite).

It is believed this standard fills a recognized need for uniform ways of designating the direction of winding of 16-mm sound film. It is definitely not the intent of this standard to indicate any preference in the direction of winding, since existing equipments are designed to use both styles.

Revised American Standard Z22.40-1950 Sound Records and Scanning Area of 35-Mm Sound Motion Picture Prints

This standard originated as an American War Standard, Z52.36–1945. It was reapproved as American Standard, Z22.40–1946, in March, 1946 and published in the April, 1946 Journal. However, in the republishing process, a minor drafting error occurred. The arrow pointing to the outer edge of the printed area fell slightly short of the outer edge. This revised standard, Z22.40–1950, corrects that error and is thus being published now as originally intended (see p. 114).

Proposed American Standard

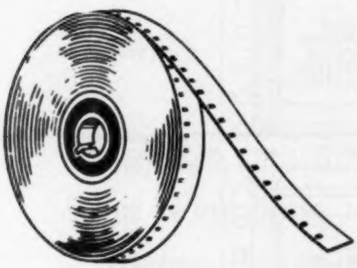
A and B Windings of 16-Mm Raw-Stock Film With Perforations Along One Edge

(Second Draft)

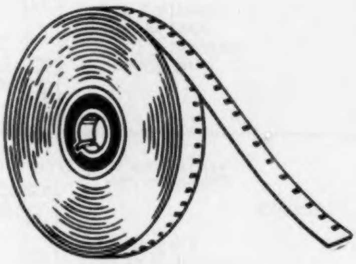
Z22.75

The purpose of this standard is to insure a uniform method of designating the types of winding (location of the perforated edge) in current use for 16-mm raw-stock film having perforations along one edge, thus to facilitate ordering and describing the film.

With both types of winding described below, the emulsion side of the film shall face the center of the roll.



Winding A
Emulsion side in



Winding B
Emulsion side in

When a roll of 16-mm raw stock perforated along one edge is held so that the outside end of the film leaves the roll at the top and toward the right, winding A shall have the perforations along the edge of the film toward the observer, and winding B shall have the perforations along the edge away from the observer. In either case, if the film is wound on a spool with a square hole in one flange and a round hole in the other flange, the square hole shall be on the side away from the observer.

No preference for either type of winding is implied since both types are required for use on existing equipment.

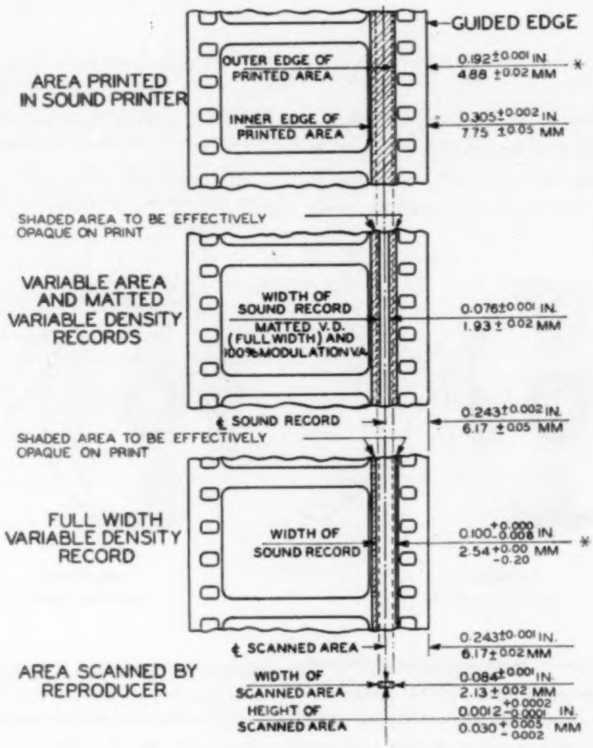
NOT APPROVED

American Standard

Dimensions and Locations for Sound Records and Scanning Area of 35-Millimeter Sound Motion Picture Prints

ASA
Reg. U. S. Pat. Off.
Z22.40-1950

Revision of
Z22.40-1946
†UDC 778.534.4



Distance Between Sound and Corresponding Picture — The sound shall precede the center of the corresponding picture by a distance of 20 ± ½ frames.

These Dimensions and Locations Are Shown Relative to Unshrunk Raw Stock.

***The only change in this standard over the 1946 edition is the correct positioning of the arrows on the dimensions marked *.**

Approved October 6, 1950, by the American Standards Association, Incorporated

Sponsor: Society of Motion Picture and Television Engineers

†Universal Decimal Classification

Edge Numbering 16-Mm Motion Picture Film

The Proposed American Standard for Edge Numbering 16-Mm Motion Picture Film has been under discussion for several years. In the original discussions, neither the 16-frame nor the 40-frame interval could be unanimously chosen for a standard. The laboratories producing 16-mm prints from original 35-mm material were desirous of retaining the 16-frame interval, while those working from original 16-mm film preferred 40-frame separation of the numerals. In the latter part of 1949, there was further discussion in an attempt to establish the 40-frame interval as a standard. Consequently, this proposed standard has been written to make 16-mm edge numbering optional, but specifying that the 40-frame interval is preferred.

Proposed American Standard **Edge Numbering 16-Mm Motion Picture Film**	Z22.83

The purpose of this standard is to establish a uniform practice with respect to the interval between edge numbers when they are latent-image printed on 16-mm raw-stock film. It is not intended to imply that all 16-mm film should be edge-numbered.

The distance between consecutive numbers shall be 40 frames. Thus, the numbers will indicate film footage, subject to a small correction for shrinkage of the film.

NOT APPROVED

Tentative Recommendations for 16-Mm Review Rooms and Reproducing Equipment

Foreword

The tentative recommendations included herewith are the result of extensive work carried on by a Subcommittee of the 16- and 8-Mm Committee under the Chairmanship of E. W. D'Arcy. It should be clearly understood that this is not a final Society recommendation, but rather that it is an interim report of the committee. The proposal is being published at this stage to make the information available to those who have use for it and to invite additional comments and discussion.

At the outset it was agreed that the primary objective of the subcommittee was to establish a primary listening standard for gaging 16-mm print quality. This decision was reached only after lengthy discussion regarding the possibility of actually specifying the ideal over-all response characteristic of 16-mm portable projection equipment. To accomplish this end, however, appeared to be an insurmountable problem because of variation in response of the portable-type loudspeakers and the varying conditions under which the equipment is used.

The problem, therefore, was approached from the other direction, namely of trying to improve and make more uniform 16-mm release prints. It then would be left to the 16-mm projector manufacturers to adjust their equipment in any way they saw fit to best reproduce these prints.

In reaching this objective, listening tests were conducted employing various wide-range two-way speaker systems as well as portable speakers normally used with 16-mm projectors. For those listening tests a wide selection of 16-mm release material was reproduced on these systems using a number of suggested frequency characteristics.

As the testing progressed, it became more and more evident that:

First, modification of the reproducer frequency characteristics from those recommended for 35-mm theater use by the Motion Picture Research Council produced little if any significant improvement in the reproduction of 16-mm prints.

Second, if a 16-mm print reproduced well, employing the 35-mm theater systems, it also reproduced well on a conventional 16-mm projector employing small portable-type loudspeakers.

Therefore, rather than try and establish any particular electrical characteristic and portable-type speaker as a recommended review room system, it was agreed to accept those characteristics recommended for theater use, since many of the present 16-mm

Third draft, dated November 15, 1950, edited and presented for publication on January 2, 1951.

producing companies and processing laboratories already have 35-mm systems in their review rooms which can readily be modified for the 16-mm reproduction.

The frequency-response characteristics shown on the following pages are identical with those established by the Motion Picture Research Council for use in reproducing 35-mm sound films in motion picture theaters.

There are theater-type speakers not covered in these recommendations. It is hoped that suitable arrangements can be made for adding curves for these and future speakers in order that the recommendations may be as up-to-date and useful as possible.

1. Scope

1.1: The purpose of this standard is to facilitate the production of 16-mm films having sound tracks of high, uniform quality. It is believed that the best way to attain this objective is to establish a reference system for judging the quality of the sound from 16-mm films. Such a system requires:

(a) a sound reproducer having standardized over-all electrical frequency-response characteristics,

(b) a projector of high quality, and

(c) a review room having good acoustical properties.[1]

The characteristics established by the Motion Picture Research Council[2] for various speaker systems used in reproducing 35-mm sound film have been adopted because extensive listening tests proved them to be optimum for reproducing sound from 16-mm film also.

Thus, the electrical characteristic is specified for each particular speaker system. Before a system other than those shown below is used, it will be necessary to make comparative listening tests to determine the proper frequency-response characteristic for that system.

2. Reproducer Requirements

2.1: Power Output: The minimum power output of the reproducer amplifier shall be 15 w. The reproducer gain control should be calibrated in db and should indicate the gain setting required to produce 10 w output from the American Standard Signal Level Test Film Z22.45. The amplifier should have enough available gain to produce at least 20 db in excess of that required to produce 10 w.

2.2: Harmonic Distortion: The reproducer amplifier shall not introduce more than 1% harmonic distortion at 10 w output and not more than 2% at 15 w at any frequency between 50 and 7000 cycles.

2.3: Signal-to-Noise Level: The over-all system noise measured electrically at the speaker terminals of the amplifier shall not be greater than 50 db. This measurement should be made with the system frequency response adjusted for the particular speaker in use and with the gain control set to deliver 10 w output when the American Standard "400 Cycle Signal Level Test Film Z22.45" is passed through the projector.

The output should be terminated in a noninductive resistive load equal to the nominal input impedance of the particular speaker system in use. The measurement should then be made without film in the gate, with the projector running and exciter lamp turned on.

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[1] "Theater acoustic recommendations of the Academy Research Council Theater Standardization Committee," *Jour. SMPE*, vol. 36, Mar. 1941.

[2] "Standard electrical characteristics for theater sound systems," *Motion Picture Research Council Bulletin*, 1948 Volume.

2.4: Frequency Response: The overall frequency-response characteristic of the projector and amplifier shall be adjusted as shown in Figs. 1 through 7, depending upon the theater speaker system to be employed. Variations are permitted from these nominal responses of ±1 db from 100 to 3000 cycles and increasing progressively with frequency to ±2 db at 7000 cycles. To adjust the system to the reverberation characteristics of a specific review room, it may also be necessary to adjust the response below 100 cycles. Variation as great as −2 db are permitted as shown on the respective curves.

These measurements shall be made with amplifier output terminated in a noninductive resistive load equal to the nominal input impedance of the particular speaker system in use. The source of signal shall be a multifre-

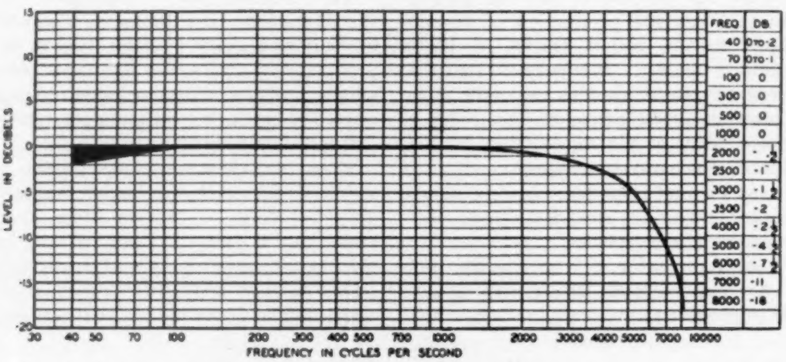

Fig. 1. Recommended electrical characteristics for 16-mm review room reproducers employing Altec Lansing Energized Loudspeaker Systems Models 75W5 and 30W5. High-frequency unit attenuation 0 to 3 db.

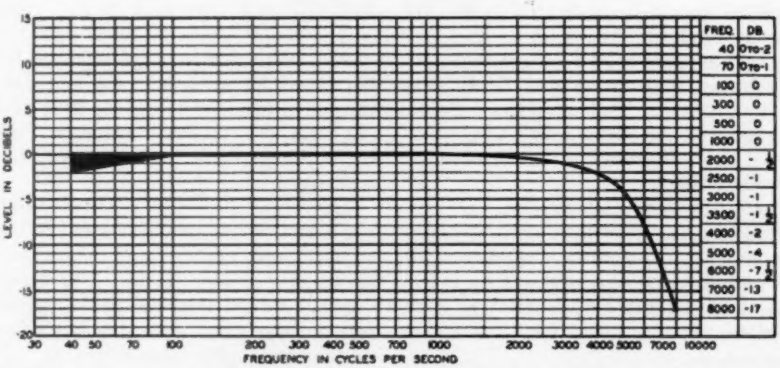

Fig. 2. Recommended electrical characteristics for 16-mm review room reproducers employing Altec Lansing Voice of the Theater Loudspeaker Systems Models A1X, A1, A2X, A2, A4X, A4 and A5. High-frequency unit attenuation 0 to 3 db.

quency test film made in accordance with American Standard Z22.44.

2.5: Uniformity of Scanning-Beam Illumination: The uniformity of scanning-beam illumination shall be such that the output from the reproducer amplifier does not vary more than $\pm 1^1/_2$ db when an American Standard Uniformity of Scanning-Beam Illumination Test Film Z22.80 is run through the reproducer.

2.6: Flutter: The flutter introduced by the reproducer shall not exceed 0.25% when using the American Standard Flutter Test Film Z22.43.

Note: This value has been selected as the maximum permissible value as measured on an RCA Flutter Bridge or on an instrument that has been adjusted to give comparable readings.

2.7: Loudspeaker Attenuation: When using the two-way loudspeakers specified in the recommendation, it is often

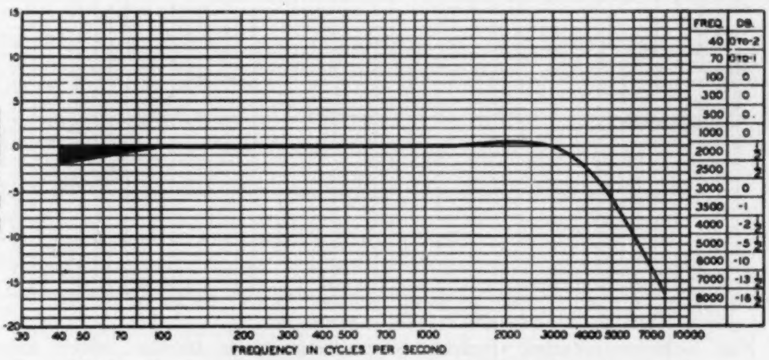

Fig. 3. Recommended electrical characteristic for 16-mm review room reproducer employing International Projector Simplex Four-Star Loudspeaker Systems Models A and B. High-frequency unit attenuation 0 to 2 db.

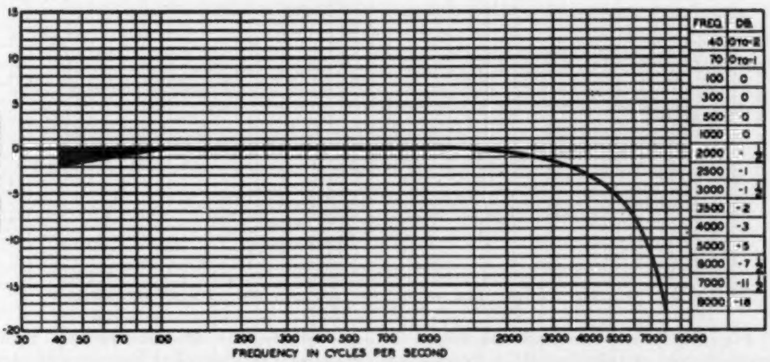

Fig. 4. Recommended electrical characteristic for 16-mm review room reproducers employing International Projector Simplex Four-Star Loudspeaker Systems Model C. High-frequency unit attenuation 2 to 3 db.

advisable to attenuate either the high- or low-frequency side of the dividing network to obtain equal acoustical response on both sides of the network cross-over frequency. Typical values of attenuation have been specified with each of the recommended response vs. frequency curves.

3. *Acoustical Requirements*

3.1: Room Reverberation Characteristics: The desirable reverberation time of a room is a function of its size. Excessive reverberation causes blurring of speech and rapidly moving staccato music. Where the reverberation time in the room is below optimum, an excessive amount of sound energy must be

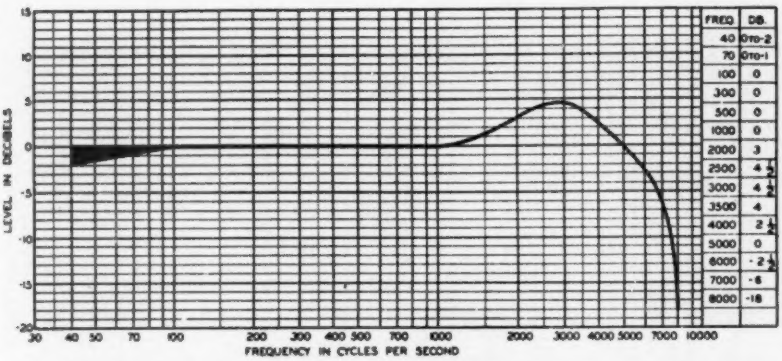

Fig. 5. Recommended electrical characteristic for 16-mm review room reproducers employing RCA Energized Loudspeaker Systems Models PG91, PG92, PG117 and PG118. Low-frequency unit attenuation 0 to 2 db.

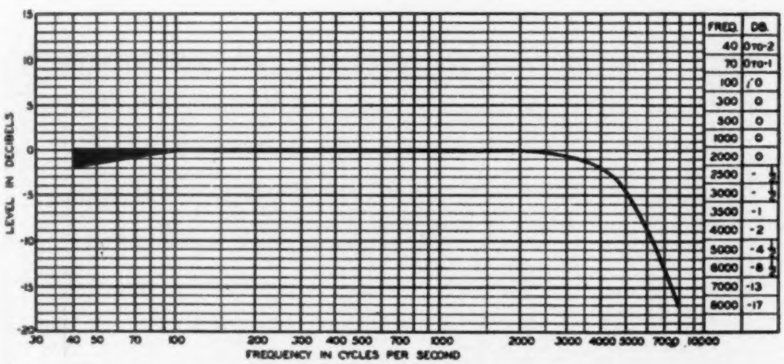

Fig. 6. Recommended electrical characteristic for 16-mm review room reproducers employing RCA Permanent Magnet Loudspeaker Systems Models PL240, PL244 and PL246. MI-9458 high-frequency unit attenuation 1 to 2 db. MI-9449 low-frequency unit attenuation 0 db. MI-9448 high-frequency unit attenuation 0 db. MI-9449 low-frequency unit attenuation 1 to 2 db.

radiated and the resultant sound is unnatural.

The optimum reverberation period varies with frequency and with the size of the room. Figure 8 gives the optimum reverberation time for theaters.

To summarize, the essential design features are:

1. A minimum volume consistent with the required seating capacity and proper auditorium proportions.

2. An auditorium width of from 50 to 70% of the length and an auditorium ceiling height of not more than 40% of the length.

3. The use of nonparallel surfaces; in particular, the floor should not be parallel to any ceiling section nor opposite side-wall sections parallel.

4. The use of convex rather than concave surfaces. In addition, the wall and ceiling surface should otherwise be broken up so as to thoroughly diffuse the sound.

5. Auditorium absorption characteristics to provide the same rate of sound

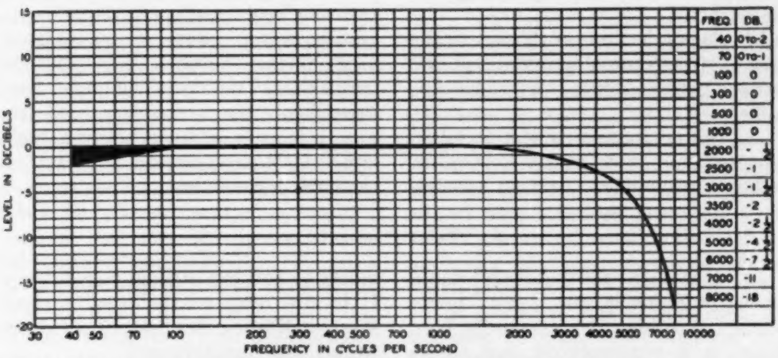

Fig. 7. Recommended electrical characteristic for 16-mm review room reproducers employing Western Electric Mirrophonic Systems Models M1, M2 and M3. High-frequency unit attenuation 2 to 4 db.

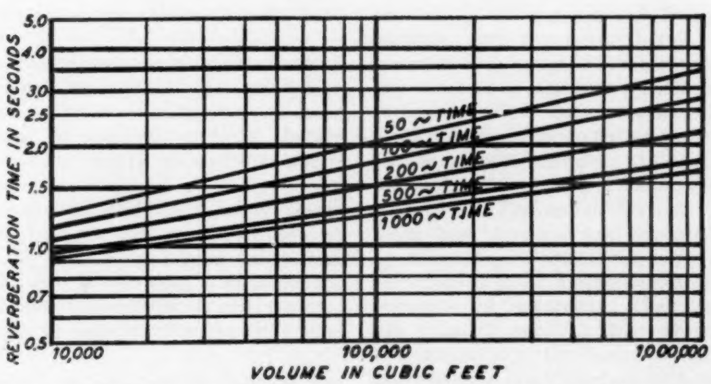

Fig. 8. Optimum reverberation time for motion picture theaters.

decay in a vertical as in a horizontal direction from side to side or from back to front walls.

6. Heavily upholstered seats and ozite-lined carpet in the aisles.

7. Backstage treatment giving a negligible amount of reflected or reradiated sound from the backstage into the auditorium.

8. A heavily carpeted stage designed for good viewing conditions from the front seating section.

9. Auditorium walls with sufficient sound insulation material to prevent extraneous noise from entering the auditorium.

10. The projection booth acoustically treated with fireproof material and projection ports equipped with acoustic baffles.

11. All equipment subject to vibration and hum such as arc generators, voltage regulators, lighting control equipment, etc., acoustically isolated from the auditorium.

12. Air-conditioning equipment of a high-volume, low air-velocity type with air ducts provided with ascoustic baffles.

Long, narrow auditoriums, high ceilings, excessively long and narrow balcony overhangs, concave focusing surfaces, and large unbroken reflecting areas should always be avoided, as acoustical faults will always result from their use.

If these recommendations are followed, the resulting auditorium will give sound (as reproduced on a modern two-way equipment) with high intelligibility, warm, natural screen presence, good balance between high and low frequencies, uniform loudness level throughout the auditorium and the proper relative balance between high-level music passages and low-level, intimate dialogue scenes.

4. *Test Procedure*

4.1: Inasmuch as the sound-reproducing equipment in review rooms usually is subject to extremely hard usage, it is recommended that equipment purporting to meet these requirements be checked at least once a week. It is also recommended that a check sheet indicating the results of these weekly tests be maintained.

Sound Committee Report

By Lloyd T. Goldsmith, Committee Chairman

It has been several years since the Sound Committee has reported to the Society on its activities and accomplishments. It has been active, however, on projects authorized by the Engineering Vice-President and the following is an account of its work to date.

A subcommittee under the chairmanship of R. T. Van Niman investigated the possible advantages of the blue-sensitive and lead sulfide types of phototubes for 35-mm theater and 16-mm projector use over the presently used red-sensitive phototubes. This is a continuing activity being carried on with manufacturers of color films; but at the present time, only the red-sensitive phototube is recommended as giving the best all-around performance with present day black-and-white and color sound tracks. Additional data now scheduled for collection may provide the basis for modifying this statement, however.

Our committee has cooperated with a subcommittee of the 16-Mm and 8-Mm Motion Picture Committee, which is working to establish electrical characteristics for 16-mm review-room reproducers.

We studied and approved proposals which lead to the standardization of 100-mil and 200-mil push-pull sound tracks used in recording original sound.

Considerable correlation has been carried on to reconcile the Society's proposed standards of flutter definition and measurement with the proposals of Dr. Kellogg's ASA Sound Committee Z-57. Agreement has now been reached and early ASA standardization will result. The original flutter proposals were formulated by the Sound Committee under the chairmanship of J. G. Frayne, who with R. Scoville, has actively followed through with the correlation.

Our committee aided in the preparation and final approval of the Society's 16-mm Sound Service Test Film Code SPSA, which has had wide sale and use in testing the performance of 16-mm sound projectors.

The proposed British standards for magnetic recording were reviewed and comment forwarded to the British Standards Institution.

It was brought to the attention of the committee that some recent screen installations in theaters resulted in excessive loss of volume and high-frequency response from the screen horns. The committee investigated, measured the loss of screen samples, and on finding it excessive, aided the manufacturer in modifying his fabric to reduce the sound loss to accepted values. As the War Standard Z52.44-1945 "Sound Transmission of Perforated Screens" had never been reviewed and processed as an American Standard, the committee circulated it to all known screen manufacturers for approval. Their recent loss data all met the War Standard, and, accordingly, the Sound Committee approved the War Standard with minor revisions, and the new proposal was pub-

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Presented on October 18, 1950, at the Society's Convention at Lake Placid, N.Y.

lished in the July, 1950, JOURNAL for a 90-day trial period leading to its eventual adoption as ASA Standard Z22.82.

The proposed American Standard for Acoustical Terminology developed by ASA Sectional Committee Z-24 on Acoustics was reviewed and suggested changes forwarded to that committee.

In May, 1948, a Subcommittee on Magnetic Recording was set up, with G. L. Dimmick as Chairman, and charged with the formulation of standard sound track dimensions and speeds of magnetic recording on 35-, 17½-, 16- and 8-mm motion picture film. With the help of several task forces assigned to specific aspects of the problem, the subcommittee prepared for the Sound Committee proposed standards which are now in the hands of the Standards Committee with the recommendation that they be published in the JOURNAL for six-month's trial and criticism. A progress report of the subcommittee was given at the 1949 Fall Convention.

The Magnetic Recording Subcommittee is about to prepare specifications for magnetic test films of the types that may be required by industry and sold by the Society. At the moment, an azimuth film, multifrequency film and buzz track appear to be most needed and will probably be made available first.

It is anticipated that problems associated with magnetic recording and reproduction will constitute the major part of the committee's work for the coming year with particular emphasis on standards, test films and television sound problems.

Theater Television Committee Report

By D. E. Hyndman, Committee Chairman

DURING 1948 AND 1949, the work of the Society's Theater Television Committee was devoted to the consideration of all engineering phases of the use of television in motion picture theaters. It reviewed the design, construction and operation of theater television equipment, from the standpoint of alterations that might be necessary within a theater, power supplies, viewing conditions, screen brightness, program distribution facilities and the like.

In June, 1949, the Federal Communications Commission requested the Society along with Paramount Pictures, Inc., and Twentieth Century-Fox Film Corp. to file a statement concerning the allocation of frequency bands for a theater television service. This request brought to an end the more or less broad general consideration that was being given to all phases of this work and forced the committee to concentrate on a statement which would outline in specific terms what the industry needed in the way of radio frequencies to establish a nation-wide theater television serv-

Presented on October 20, 1950, at the Society's Convention at Lake Placid, N.Y.

ice. On August 29, 1949, the committee filed such a statement with the Commission.

It was realized at that time that some of the conclusions reached by the statement, while based on good engineering judgment, could not be backed up by actual engineering data. It was also realized that such concrete information would have to be provided at the time of the public hearing if the industry had any hopes of having the FCC grant their request.

1950, therefore, has been devoted to securing the technical data on distribution facilities, which would substantiate the 1949 statement. As a means to this end, a subgroup was established under the chairmanship of George L. Beers of RCA. This group is composed of theater television equipment manufacturers and representatives of the common carriers. They were requested to investigate four specific characteristics of a theater television distribution system. The first dealt with the bandwidth required, the second with permissible signal-to-noise ratio, the third with distortion, and the last with the compression which could be tolerated on such a distribution system.

RCA agreed to provide the laboratory facilities for conducting these tests, provided the committee reviewed the test methods proposed and gave its assistance in interpreting the test results. At present, work is in progress on the first two of the assigned tasks, namely bandwidth and signal-to-noise. The subcommittee has approved the test methods prepared by Otto Schade and is awaiting an opportunity to judge the results on a large-screen theater system. So far, only limited viewing tests have been conducted and these on a small-screen direct-view cathode-ray tube. As soon as a large-screen laboratory setup is made available, it is hoped definite conclusions can be reached.

From the standpoint of practical operating problems, a wealth of experience will be gained from the actual theater installations that have been made in recent months. Nine theaters in seven cities now have equipment installed and are carrying weekly programs of various sports events. It is reported that before the first of the year, there will be 16 theaters so equipped. Since both cable and radio facilities are being used for program distribution to these theaters, much will be learned that will assist Mr. Beers' group in reaching rapid conclusions.

The Theater Television Committee plans to continue this activity to arrive at the answer to the basic engineering problem. When this preliminary work has been completed, it is anticipated that appropriate standards and recommendations will be set up as the Society has done in the past in the field of motion pictures.

Spring Convention 1951

APRIL 30—MAY 4 The Society's 69th Convention in $34\frac{1}{2}$ years is also the 69th to be held under the able tutelage of Bill Kunzmann, Convention Vice-President. His staff of Chairmen and Vice-Chairmen for the Spring Convention have now been appointed and by the end of January will have completed the general schedule of events as well as preliminary preparation for details of the program.

NEW YORK CITY Since the Papers Committee Vice-Chairman who resides in the city where a convention is being held, automatically becomes Program Chairman, the choice of New York gives the responsibility to Bill Rivers. Among other things, he will develop the details of papers presentation along lines suggested by Ed Seeley, Papers Chairman, and will prepare manuscript copy of the Tentative and Final Programs.

HOTEL STATLER Technical Sessions will be held in the Georgian Room on the Ballroom floor of the Statler rather than in the Salle Moderne as in the past, because increased attendance has forced a move to a larger meeting room. Headquarters for the Ladies' Committee will be in Room 129 and Conference Rooms 2 or 3 on the Mezzanine have been reserved for meetings of technical committees throughout the week. The Publicity Committee will set up shop in Conference Room 8.

PAPERS Members of Ed Seeley's Papers Committee are rounding up groups of related papers on subjects that are either of special technical interest at this time or have been neglected at recent conventions. As a consequence, the program will include several symposium-type sessions, each of which will include all or nearly all convention papers related to a particular topic. Members or guests whose interests and whose time are limited will be able to derive maximum benefit from minimum participation.

ADVANCE Realistic deadline dates for printed material have been established as objectives for authors and Papers Committee members. The schedule of sessions, symposium titles, information on tours and major entertainment features must be on the editor's desk by February 19, so the Advance Notice which includes the hotel room reservation card can be printed and ready for mailing to all members on Monday, March 5.

AUTHORS By Friday, February 23, Bill Rivers must have received from each prospective author, the *white* copy of the 69th Convention Author's Form, and two copies of a 50- to 75-word abstract for use in preparing original typewritten copy of the Tentative Program. Bill also requires two self-addressed business envelopes ($4\frac{1}{4} \times 9\frac{1}{2}$ in. or thereabouts), to simplify prompt mailing of subsequent Papers Committee correspondence.

TENTATIVE Copy for the Tentative Program is scheduled to be ready for the printer on Monday, March 5. Since the convention is to be in New York, Vic Allen will arrange for printing. He expects to have the Tentative addressed to all members and in the mail, by first class, on Monday, March 26.

MANUSCRIPTS Each author must send the *buff* copy of the Author's Form with his manuscript and one full set of illustrations to Vic Allen at Society headquarters by March 23. The manuscript should be typed double-spaced on good bond paper; send the *original*, not carbon copy. Also, send Vic the original illustrations, being certain to pack them securely. Good photo-engravings cannot be made from poor reproductions of original art work.

FINAL The Final Program listing presentation times of all papers will be ready by Monday, April 23. Each author, as well as each technical session chairman and vice-chairman, will be notified of his schedule in advance so he can plan his convention week before leaving home. This is an ambitious program that calls for active support by *all* members, so give the Papers Committee and the 69th Convention Program Chairman a hand. If you are preparing a paper, please observe these deadline dates.

If you have any questions, write to Ed Seeley or Bill Rivers. Secure *Author's Forms* and *Hints to Authors* from the nearest Vice-Chairman of the

PAPERS COMMITTEE

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National Film Board of Canada, John St., Ottawa, Canada

For High-Speed Photography
J. H. Waddell
Wollensak Optical Co., 850 Hudson St., Rochester, N.Y.

As soon as the Committee's roster is complete, it will be published with the addresses of all members included.

Atlantic Coast Section Meeting

Tom H. Miller of Eastman Kodak Co., Rochester, gave an unusually interesting talk on photographic color problems before the Atlantic Coast Section in New York on December 12. A large number of colored slides were used to illustrate each point of the color problems discussed.

Mr. Miller first took up the effect of the characteristics of the light source on a color photograph. Color distribution in the source is of secondary importance in taking black-and-white pictures, partly because the finished picture must necessarily look different from the original scene. The best result is one which is pleasing to the viewer. However, a color picture must, at least in most cases, reproduce the color of the original scene as accurately as possible. But here the photographer runs into trouble due to variations in illumination of the original which may not give acceptable pictures even if perfectly reproduced by the photographic process.

The effect of different illumination of the subject was illustrated by pictures taken at midday and late afternoon of the same subject. Using film balanced for daylight (midday sunshine) the late afternoon pictures were quite obviously different and in the case of portraits less desirable, although for special effects the warmer light of late afternoon might give just the effect the photographer wants.

The speaker called attention to a variety of effects which may occur in outdoor illumination, so that the color balance may be shifted to the yellow, red or blue, depending on the subject and atmospheric conditions. Usually people do not observe these changes in illumination as accurately as the film does, because of adaptation of the eye. This was illustrated by comparison of pictures taken under outdoor and indoor illumination with the same film, showing marked difference in color balance, although an observer would have said that

the illumination was white in each case. Another characteristic of the illumination which is important in color photography is specular or diffuse reflection. In general saturated colors cannot be obtained by diffuse illumination, as for example on a cloudy or overcast day.

Mr. Miller then discussed certain characteristics of color photographing materials, particularly their inability to reproduce accurately certain colors. Most commercial materials are balanced to give good flesh tones but this does not mean that all colors will be perfectly rendered. Due to differences in processes the colors not perfectly reproduced will vary from one material to another. Consequently the only way to be sure of obtaining desired results is to make test exposures on each fabric, material and paint used in a production.

Even this is not enough since by adaptation, the eye adjusts itself to the predominant illumination and judges adjacent or subsequent colors in relation to it. This was illustrated by a series of pictures in which each varied only slightly in color balance from the preceding one. Most of them were quite acceptable although the range of color balance was very great. However, a direct change from one end of the series to the other was very noticeable and undesirable. This accounts for the fact that a color film which is satisfactory by itself may not look right when spliced between films having considerably different balance. The effect of background and surrounding illumination on apparent color rendition was also shown to be considerable.—C.R.K.

The 1951 Journal

As the Society grows, in size, occasional breaks with tradition are necessary to accommodate the diverse needs of an expanding membership. One came a year ago when "Television" was added to the Society's name, recognizing that its new importance had placed television firmly alongside motion pictures and synchronized sound. Another break occurs with the change from a single- to a two-column format beginning with this issue of the Journal.

Of several reasons for making the change at this time, two stand out: First, the amount of publishable material accepted by the Board of Editors has increased steadily for four volumes in succession, requiring the Editor to exceed his last two yearly forecasts of Journal pages to be printed. The trend will doubtless continue. Second, there has been a steady rise in cost of publication resulting from increased charges for paper, engravings and labor. None of these is likely to be reduced.

Here are two opposing factors—one highly desirable, the other inevitable—which have put the squeeze on the Society's publications program.

Under the present circumstances, two columns, with reduced margins, held the only hope for real savings. Changing the trim size by a small amount would have helped even more but seemed undesirable for the time being. Adopting a different printing method could produce no real economy because of the small press run. Any reduction in quality of the paper would have been folly, for the grade used in 1950 was about the cheapest available and often failed to yield adequate halftone illustrations.

The present format (two 13-pica columns retaining the previous typeface, Monotype 8A, set in 9-pt. on 10-pt. body) permits 37½% more information to be placed on a single 6 × 9 in. page of text. Printing and binding economies achieved in this way will just about offset certain increased charges that became effective in November, 1950, and others that start with January, 1951.

As a result, each Society dollar spent for publications in 1951 will buy as much printed information as it would have a year ago, even though costs have increased substantially during the intervening period.

Engineering Activities

Television Film Equipment

During 1950, the Society joined with the Institute of Radio Engineers and the Radio-Television Manufacturers Association (RTMA) in a cooperative program of standardization and exchange of technical data. One result was the combining of two Society Committees, the Films From Television Committee and the Television Film Projectors Committee, with similar RTMA projects, under a Television Film Equipment Committee. This joint group under the enthusiastic Chairmanship of Frank N. Gillette, General Precision Laboratory, met last October during the Convention at Lake Placid and again on January 4 in New York City.

At the recent meeting, agreement was reached on a Proposed Standard for 16-Mm Projectors for Television Film Chains Operating on Full-Storage Basis. To bring the proposal into line with the standards policies of RTMA and SMPTE, certain proprietary references were deleted and it has become largely a detailed specification for performance of the equipment. Tests, methods of measurement, references to specific test films and to particular test equipments are also included.

The Committee received favorably suggestions for area of scan on 16-mm film and for picture area in video recording. The dimensions considered with the reason for being selected will be put into the form of a Proposed American Standard. After balloting of the entire Committee, the proposals will doubtless be published in the Journal for a short period of trial and criticism.

Substantial agreement was also reached on a proposal to publish recommended standard dimensions for slides and opaques. The 2 × 2 in. transparent slide and the 4 × 5 in. opaque were considered most desirable, so the Committee will shortly vote upon them.

16-Mm and 8-Mm

The 16-Mm and 8-Mm Motion Pictures Committee, under the chairmanship of Henry Hood, has been exceptionally active. Several of the projects will soon appear in the Journal, notably the proposals on 16-mm and 8-mm film splices and on 16-mm projection reels. One project, "Recommendations for 16-Mm Review Rooms and Reproducing Equipment," developed by a subcommittee under the chairmanship of E. W. D'Arcy, appears elsewhere in this issue of the Journal. It is being published as an interim committee report in the hope that sufficient comments will be received during the ensuing year to enable the committee to formulate proposals for standardization.

Sound

At the Lake Placid Convention, the Sound Committee, under Acting Chairman, John Frayne, was faced with the urgent problem of reaching agreement on proposed standards for magnetic sound tracks on film. Protracted delay would result in incompatibility with the first equipments appearing on the market. Even more serious is the probability that the first manufacturer to produce a magnetic sound projector commercially would set the standard. With this understanding, the Committee hammered out Proposed American Standards for Magnetic Sound Track on 35- and 17½-Mm Film, 16-Mm Film, and 8-Mm Film and submitted them to the Standards Committee for its recommendations on publication for a 90-day trial. They will probably be published within the next few months.

The status of the Proposed American Standards for Sound Transmission of Theater Projection Screens published for trial in the July, 1950, Journal, was reviewed. Inasmuch as no adverse criticism had been received, it was agreed to submit it to the Standards Committee for recommendations on final approval as an American Standard.

In addition, plans were made for increasing activity on lead sulfide phototubes and standards for 16-mm magnetic film, coated full width.

BOOK REVIEWS

Fundamentals of Acoustics

By Lawrence E. Kinsler and Austin R. Frey. Published (1950) by John Wiley, 440 Fourth Ave., New York 16. 499 pp. + 5 pp. appendix + 3 pp. glossary + 6 pp. index. 163 illus. $5\frac{1}{2} \times 8\frac{1}{2}$ in. Price $6.00.

This book presents the fundamentals underlying the generation, transmission and reception of acoustic waves. It was prepared as a textbook on the fundamentals of acoustics and is a very usable book for this purpose. The illustrations are good and each chapter is followed by a set of very well chosen problems.

The first half of the book develops the theory of vibration of solid bodies and the propagation of sound waves through fluids. It starts with simple oscillators having a single degree of freedom. In a logical manner follow chapters on the vibration of strings, bars and stretched membranes. The general acoustical wave equations for fluids are developed and applied particularly to plane and spherical waves with various boundary conditions including transmission from one medium to another. Then follows the fundamental theory of the radiation of sound from vibrating bodies of various sorts such as pistons, vibrating spheres, etc. These principles are applied to Helmholtz resonators and acoustic filters. Finally in Chapter 9 there is a brief but excellent treatise on the absorption of sound waves under various circumstances.

The theory developed in the first half of the book is applied to direct radiator loudspeakers and horn-type loudspeakers. Chapter 12 is a discussion of microphones; carbon, condenser, crystal, electrodynamic moving coil and velocity ribbon. The electroacoustical reciprocity theory is very clearly presented and applied to the calibration of these microphones.

There is a chapter on psychoacoustics dealing with the mechanism of hearing, loudness, masking, binaural localizations, etc., followed by chapters on each of the following general fields: architectural acoustics, underwater acoustics and ultrasonics.

The authors have maintained a very good balance between the fundamental aspects of the physics of the problems and the engineering applications. Numerous references are made to analogous electrical problems, but this is not overdone and each important equation is derived from the fundamental laws of physics.

It should serve as a very useful text in senior college and graduate courses, both in physics and engineering classes.—Dr. Harvey Fletcher, 5 Westminster Rd., Summit, N.J.

Fundamentals of Optics, New 2d Ed.

By Francis A. Jenkins and Harvey E. White. Published (1950) by McGraw-Hill, 330 W. 42d St., New York 18. 626 pp. + 4 pp. Answers to Problems + 17 pp. index + xi pp. 447 illus. 6×9 in. Price $7.00.

This book represents a new edition of the authors' well-known *Fundamentals of Physical Optics*, first published in 1937. As a physical optics text, it is hard to see how this book could have been improved, and it is gratifying to find that it has been reprinted almost without change in the new edition. A few sections have been added, covering the quantum nature of light and some modern developments such as the Twyman-Green interferometer, phase-contrast microscopes, interference filters, and gratings giving a 'blaze' in one order. Each topic has been treated with just the necessary degree of detail for students' use, and difficult side-issues have been carefully avoided. Having read any chapter, the reader has the pleasant feeling that now he knows all about that sub-

ject. The diagrams are clear, and the photographic illustrations excellent. A particularly gratifying feature of the treatment is that mathematics is used only to provide a deeper analysis of some physical phenomenon which has already been explained in a clear qualitative way. Too many teachers reverse this process, and feel that a mathematical treatment is the whole story. The book can be confidently recommended as an unusually clear exposition of the nature and properties of light.

The new edition also contains a lengthy section (175 pp.) on geometrical optics, which justifies the more general title. Unfortunately the method of treatment here is not nearly as good as that adopted for the physical optics part. Fermat's and Malus' theorems, and the dispersion of glass, are clearly treated, but they are actually physical optics phenomena. No less than 52 pp. are devoted to the formulas for conjugate distances and magnification, first for a thin lens, then for a single refracting surface, then again for a thick single lens, and finally for a spherical mirror. Surely it would be simpler, and more satisfying to the student, to derive the formulas for a general optical system defined by its two focal points and two principal points, and then to regard thin lenses and single surfaces as simple special cases.

It is good to find a brief reference to the photometry of optical systems and the theory of image brightness. Spectroscopic and other prisms are adequately covered. The properties of chromatic aberration are described clearly, but spherical aberration is treated in unnecessary detail. The references to coma and the sine condition suffer from the usual misunderstandings; for example, the term "sine condition" is used first to refer to the "sine theorem" (Eq. 8l, p. 121), but later it is used to refer to the difference Δf between the focal lengths of a lens for paraxial and marginal rays (Fig. 9K). The word "coma" is correctly used as a transverse measure of an aberration pattern in Fig. 9I(b), but in Figs. 9K and 9L, and in Table 9III, the same term is used to represent the longitudinal difference between the Δf curve and the spherical aberration curve. Obviously both meanings of the same word cannot be correct. The diagrams of distortion (Fig. 9T) are misleading, for when a lens suffers from barrel distortion, all parts of the image are too small, the corners being excessively reduced in size; likewise in pincushion distortion all parts of the image are too large, the corners again being excessively so. Figure 9V, (b), is incorrect, for a single lens with central passage of the light cannot possess any lateral chromatic aberration. This is an aberration of the chief ray, and will appear only where the chief ray has been dispersed into a spectrum by eccentric passage through a lens. The Huygens' eyepiece is referred to in 9.11, line 1, as an achromatic system; this is, however, contradicted later in the same paragraph. There are two errors in labeling of lens cross-sections: in Fig. 10C, the diagram shows the Zeiss Topogon, not the Ross Wide-angle, and in Fig. 10G, the lens shown is the "Varo," not the "Zoomar." The Galilean telescope diagram in Fig. 10R is incorrect, for the eye is actually the exit pupil, and only those rays which enter the eye should be considered. The entrance pupil of a Galilean telescope is virtual and situated at a considerable distance behind the eye.

The book is very well produced, on good paper, and beautifully printed. A series of useful review problems has been included at the end of each chapter.—R. KINGSLAKE, Eastman Kodak Co., Rochester, N.Y.

Electrical Engineers' Handbook -Electric Communication and Electronics, Vol. II, 4th Ed.

Edited by Harold Pender and Knox McIlwain. Published (1950) by John Wiley, 440 Fourth Ave., New York 16. i–xiii + 1,564 pp. including approx. 130 tables and approx. 1,050 illus. + 54 pp. index. $5\frac{1}{2} \times 8\frac{1}{4}$ in. Price $8.50.

This edition has been entirely rewritten and enlarged to meet the widening fields of communication and electronics. Each section is written by an expert in that field and is accompanied by a bibliography.

The twenty-three sections cover a wide variety of electronic applications as well as fundamental properties of materials and

circuit elements. Frequency modulation, television and radar have been given considerable space.

As is the case with any handbook attempting to cover such a wide field, the space devoted to any one subject must be small compared to a textbook on that subject. In the present volume the editors and authors have shown good judgment in selecting tables and formulas to which a worker familiar with the subject may refer, and sufficient description so that one unfamiliar with the particular subject may obtain a good introduction to it.—CLYDE R. KEITH, 5 N. Terrace, Maplewood, N.J.

Television, Volume V (1947–1948)

Edited by Alfred N. Goldsmith, Arthur F. Van Dyck, Robert S. Burnap, Edward T. Dickey and George M. K. Baker. Published (1950) by *RCA Review*, Radio Corporation of America, RCA Laboratories Div., Princeton, N.J. i–x + 458 pp. + 3 pp. summary. 315 illus. 6 × 9 in. Price, $2.50, plus $0.20 per copy for postage to countries other than U.S.

Television, Volume VI (1949–1950)

Same editors and publisher. i–x + 402 pp. + 20 pp. appendix. 284 illus. 6 × 9 in. Price, $2.50, plus $0.20 per copy for postage to countries other than U.S.

Television, Volumes V and VI, are respectively the eleventh and twelfth volumes in the RCA Technical Book Series and the fifth and sixth volumes devoted exclusively to television.

The books are comprised of a compilation of reprints of articles by RCA authors which appeared in *RCA Review*, *RCA Licensee Bulletin*, *Broadcast News*, *Proceedings of the I.R.E.*, the JOURNAL of this Society, *Communications*, *Teletech*, *Journal of the Optical Society of America*, *Electronics* and *Harvard Business Review*.

In the appendix of Volume VI is given a complete television bibliography of technical papers by RCA authors for the period 1929 to 1950. Of the total published within the periods covered by *Television, Volumes V and VI*, selected articles are reprinted in full, others in summary form only, while the remainder are omitted except for their listing in the bibliography.

The papers are presented in each of these volumes in six sections: pickup, transmission, reception, color, ultra-high frequency and general. Within each of these sections, distinct phases of television development are covered by three types of articles: (1) pure theory and analyses of performance factors, (2) new techniques and proposed new designs not yet reduced to practice and (3) descriptions of new equipment, facilities, methods, techniques and concrete applications of principles reduced to practice.

Material of the first type serves as a guide for the conception and development of advanced television designs of the future. An outstanding article by Otto H. Schade is entitled "Electro-Optical Characteristics of Television Systems." It is so advanced and basic as to be of permanent value as a text.

Material of the second type forms a basis of designs of tomorrow's improved television. An example is entitled "Standardization of Transient Response of Television Transmitters" by R. D. Kell and G. L. Fredendall.

Of the third type, descriptions of new equipment are published soon after the equipment design is completed. Thus, such descriptions represent the latest equipment as of that date. Examples are: "New Television Field Pickup Equipment Employing the Image Orthicon," by J. H. Roe, and "Development of a Large Metal Kinescope for Television" by H. P. Steier, et al. Descriptions of most of the major equipment and circuit features now constituting present-day television systems may be found in these two, together with preceding volumes of *Television*.

Television papers by RCA authors are highly authentic because the findings are the results of intensive and extensive activities of the writers in all phases of television, each of whom is a specialist in his particular field.

These volumes contain a wealth of authentic television information in a concise form and they should be included in every engineer's television library.—FRED G. ALBIN, 241 S. Wetherly Dr., Beverly Hills, Calif.

Proceedings of the National Electronics Conference, Vol. 5

Published (1950) by National Electronics Conference, Inc., 852 E. 83 St., Chicago 19. i–x + 581 pp. text + xi–xxi pp. Contents, Previous Issues. Approx. 600 illus. + numerous tables. 6 × 9 in. Price $4.00.

This book is intended to serve as a permanent record and handy reference of the papers presented at the National Electronics Conference in 1949. Since only a small group can attend such a conference, the publishing of this volume allows all engineers to receive the benefits of the papers. Many papers which are presented at such meetings are never published elsewhere, consequently this provides the only permanent record of these papers.

There is not sufficient space here to review each of the 59 papers included in the book. However, it can be said that the papers range from basic theory to component design and application. Subjects covered include audio-frequency, supersonics, magnetic devices, vacuum tubes, circuits, theory of communication, antennas, television, measurements, computers, electronic instrumentation and others. One paper, "The Magnetic Cross Value and Its Application to Subfrequency Power Generation," presented a very interesting new magnetic device. The analysis of the operation of this device was well presented. It is refreshing to find that we are still discovering new principles in magnetism, one of the older phases of electronics.

It is unfortunate that no attempt was made to group papers on the same general subject or to provide an index which would facilitate rapid exploration of the volume to find everything on a particular subject.

Since the discussion of papers at such meetings frequently adds important information it is regrettable that no comment on the discussions of these papers is included.

In spite of these shortcomings the N.E.C. is to be commended for publishing its Proceedings, and it is hoped that other conferences will soon follow suit.—Ogden Prestholdt, Columbia Broadcasting System, 485 Madison Ave., New York 22.

Manuel de Sensitometrie (3d ed.)

By L. Lobel and M. Dubois. Published (1950) by Publications Photographiques Paul Montel, 189, Rue Saint-Jacques, Paris (5^e). 216 pp. 103 illus. 5⅜ × 7¼ in. Price 375 francs.

This elementary book gives the principal definitions concerning sensitometric measurements, some of the properties of the characteristic curve, and a review of the chief systems used for the definition of the negative emulsion speed. It includes a chapter on paper sensitometry and the choice of printing conditions, and another on sensitometry for positive films used by projection.

It also gives information on reversal development, including the influence of the solvent action and that of the second exposure, on intensifying and reducing processes, on the control of color photography and the use of the masking method.

Finally, about forty pages concern the elementary principles of sound recording and the application of sensitometry to sound film.

As regards the apparatus used in sensitometry, the descriptions are very short and the authors emphasize the densitometers designed by Mr. Lobel.

This booklet, despite a few errors and many oversimplifications, should be useful to amateurs and beginners in photographic science.—R. Pinoir, Kodak-Pathé, 30, Rue des Vignerons, Vincennes, France.

Journals Available: The following back numbers of the Journal are available from Mr. John R. Bizzelle, 419 West 48 St., New York 19, N.Y.: Oct. 1917, $1.00; Apr. 1918, $1.00; Sept. 1931 (2 cys) $.50 each; Nov. 1931, $.50; Jan. 1935, $.50; all 12 issues for 1942 at $.25 each; all 12 issues for 1943 at $.25 each; all issues for 1944 (except Mar., Apr. and May) at $.25 each; all 12 issues for 1945 at $.25 each; and Jan., Feb., May, June, July, Aug., Sept. and Oct. 1946 at $.25 each.

New Members

The following members have been added to the Society's rolls since those published last month. The designations of grades are the the same as those used in the 1950 Membership Directory.

Honorary (**H**) Fellow (**F**) Active (**M**) Associate (**A**) Student (**S**)

Allen, William H., Commercial Photographer. **Mail:** 721 E. Fayette St., Syracuse 3, N.Y. (**A**)

Barnes, Carl E., Director of Chemical Research, Arnold, Hoffman & Co., Providence, R.I. (**A**)

Beibin, Harold, Film Recording Engineer, Allen B. Du Mont Laboratories, Inc. **Mail:** c/o Brown, 240 W. 98 St., New York, N.Y. (**A**)

Besse, Armand, Sales Manager, Perkins Electric Co., Ltd. **Mail:** 9370 St. Hubert St., Montreal 12, Quebec, Canada. (**A**)

Clark, Walter M., Technical Photographer, Northrop Aircraft, Inc. **Mail:** 2907 Gibson Pl., North Redondo, Calif. (**A**)

Dare, Doug, Motion Picture Cameraman, Sam Hayes Productions. **Mail:** 600 N. Maple St., Burbank, Calif. (**M**)

Darmstaedter, Eric, Vice-President, Reeves Equipment Corp. **Mail:** 10 E. 52 St., New York, N.Y. (**A**)

Dierken, Kenneth C., American Television Inst. **Mail:** 534 Wellington, Chicago 14, Ill. (**S**)

Forbes, Richard B., Hollywood Sound Inst. **Mail:** 1021 Palm Ave., Los Angeles 46, Calif. (**S**)

Fung, David T., New Institute for Film and Television. **Mail:** 435 W. 123 St., New York, N.Y. (**S**)

Grossman, Milton B., Electrical Engineer, Otto K. Olesen Co. **Mail:** 10401 Tuxford St., Sun Valley, Calif. (**A**)

Hughes, Lafayette M., Jr., Producer and Director, Hughes Sound Films. **Mail:** 21 S. Downing St., Denver, Colo. (**M**)

Johnson, Carl M., Head, Technical Information Div., U.S. Navy Electronics Laboratory. **Mail:** 336 W. Upas St., San Diego 3, Calif. (**A**)

Katz, Leonhard, Engineer, Raytheon Manufacturing Co. **Mail:** 19 Ward St., Woburn, Mass. (**A**)

Kenworthy, N. Paul, Jr., 10710 Strathmore Dr., Los Angeles 24, Calif. (**S**)

Keough, James L., Still Camera, Projector and Movie Camera Repairman, Craig Movie Supply, and self. **Mail:** 6548 23d Ave., N.E., Seattle 5, Wash. (**M**)

Kish, Frank, Photographer, National Advisory Committee for Aeronautics. **Mail:** 4481 W. 51 St., Cleveland 9, Ohio. (**A**)

Kusack, William P., Chief Engineer, Balaban & Katz Television. **Mail:** Station WBKB, 190 N. State St., Chicago 1, Ill. (**M**)

Lantz, Donald R., Assistant Director, Dept. of Audio-Visual and Radio Education, International Council of Religious Education. **Mail:** 206 S. Michigan Ave., Chicago 4, Ill. (**A**)

Lewis, Louie L., Chief Engineer, WOI, WOI-FM, WOI-TV., Iowa State College, Ames, Iowa. (**M**)

Matilla, Augusto M., National Supply S.A. **Mail:** P.O. Box 2909, Caracas, Venezuela. (**A**)

Motts, Gordon H., Supervisor, Still and Motion Pictures, Army Field Forces, Bd. #4, Ft. Bliss. **Mail:** 613 Mission Rd., El Paso, Texas. (**A**)

O'Byrne, Frank E., General Manager, Queensway Studios. **Mail:** 277 Victoria St., Toronto, Ontario, Canada. (**M**)

Phelan, Charles W., Owner, Films for Television, Inc. **Mail:** Harbor Ave., Marblehead, Mass. (**A**)

Reiter, Abraham, Instructor, Audio Engineering, University of Hollywood. **Mail:** 3808 W. Alameda Ave., Burbank, Calif. (**A**)

Robyn, Abe, Sound Technician, Universal Recorders. **Mail:** 850½ N. Edinburgh Ave., Los Angeles, Calif. (**A**)

Shelton, Aaron, Chief Engineer, WSM-TV. **Mail:** 2901 23d Ave., S., Nashville 5, Tenn. (**M**)

Steadman, Loren L., 2911½ 11th Ave., Los Angeles 18, Calif. (**S**)

Williams, David L., Advisory Engineer, Lamp Div., Commercial Engineering Dept., Westinghouse Electric Corp., Bloomfield, N.J. (**M**)

Woodside, Robert L., Sound Technician and Mixer, U.S. Air Force, Lookout Mountain Laboratory. **Mail:** 8935 Wonderland Ave., Hollywood 46, Calif. (**M**)

CHANGE IN GRADE

Jacobsen, Roger G., Supervisor, Audio-Visual Installations, University of Washington. **Mail:** 11350 21st Ave., N.E., Seattle, Wash. (**S**) to (**A**)

DECEASED

Lyons, Thomas T., Projectionist, National Theaters Amusement Co., 444 W. 56 St., New York 19. (**A**)

Obituary

Albert S. Howell, Chairman of the Board of Bell & Howell Co., died at the age of 71 on January 3 in Chicago. He had retired from active service in 1940 from the company which he had helped form in 1907.

He was born in 1879 in West Branch, Mich., and became an apprentice at 16 for the Miehle Printing Press Co. He finished high school in night attendance and later studied in night classes at the Armour Institute of Technology. From his experience in his teens repairing motion picture cameras, his inventions led him to getting patents on 65 photographic devices.

Three of his inventions are credited as forming much of the basis for standardization on the 35-mm film width early in the 1900's and the ensuing rapid progress of the industry. His inventions were the Bell & Howell film perforator (1908), the continuous printer (1911) and a standard camera. His first patent was on a 35-mm projector and that led to the formation of the Bell & Howell Co.

Mr. Howell was an Honorary Member of this Society and he was honored in 1927 by receipt of the Wetherill Medal from the Franklin Institute. He was one of three men who have received life membership in the American Society of Cinematographers, the others having been Thomas A. Edison and George Eastman.

Meetings of Other Societies

Inter-Society Color Council, Annual Meeting, Feb. 28, Wardman Park Hotel, Washington, D.C. The ISCC meeting will consist of three sessions. In the morning a Discussion and Business Session will be devoted to presentation and discussion of various Color Problem Committee reports, and reports from chairmen of delegates from each Member Body. The afternoon session will consist of a symposium of reports and demonstrations on Color in Government, a program arranged under the chairmanship of Dr. Deane B. Judd. In the evening the Photometry and Colorimetry Section of the National Bureau of Standards will hold Open House for the group.

Optical Society of America, Mar. 1–3, Washington, D.C.

American Physical Society, Mar. 8–10, Pittsburgh, Pa.

American Physical Society, Apr. 26–28, Washington, D.C.

Acoustical Society of America, May 10–12, Washington, D.C.

American Physical Society, June 14–16, Schenectady, N.Y.

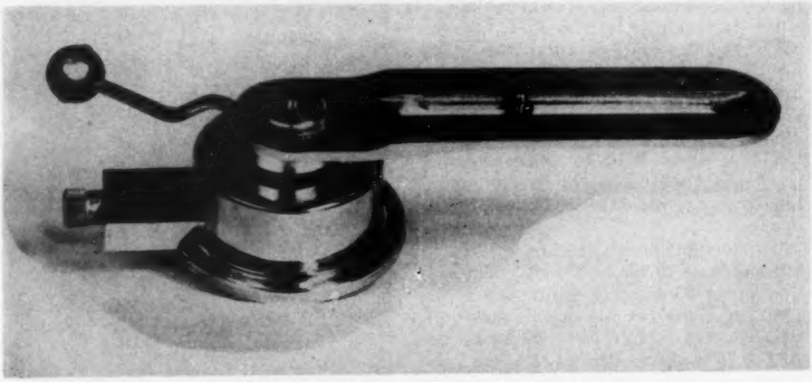
American Physical Society, June 25–28, Vancouver, Canada

American Institute of Electrical Engineers, June 25–29, Toronto, Canada

Biological Photographic Association, 21st Annual Meeting, Sept. 12–14, Kenmore Hotel, Boston, Mass.

New Products

Further information about these items can be obtained directly from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of news items does not constitute an endorsement.



The Hydra Pan Head is a new control device available from Hydra Pan Head Co., 2800 Clearwater St., Los Angeles 39, Calif. It is mounted on the tripod or tripod head and is hydraulically controlled to achieve maximum smoothness and horizon parallel. The Hydra Pan Head is designed for making murals with still cameras and panoramic pictures with motion picture cameras using telephoto lens.

Proceedings of the Symposium of Improved Electronic Components

This 236-page, illustrated book contains papers by 42 electronic authorities and experts in the military, manufacturing and engineering fields. The volume is the result of a symposium sponsored by the American Institute of Electrical Engineers, Institute of Radio Engineers and the Radio-Television Manufacturers Assn., with participation by the U.S. Dept. of Defense and the National Bureau of Standards. It contains articles on miniaturization, printed circuits, glass capacitors, quality resistors, improved tube design and the views of aircraft, naval and military experts. The sponsors have arranged distribution of the *Proceedings* at $3.50 a copy, postpaid if check accompanies the order sent to: The Tri-Electro Co., 1 Thomas Circle, Washington 5, D.C.

SMPTE Officers and Committees: The Roster of Society Officers was published in the May 1950 Journal. For Administrative Committees see pp. 515–518 of the April 1950 Journal. The most recent roster of Engineering Committees appeared on pp. 337–340 of September 1950 Journal.

Society of Motion Picture and Television Engineers

342 Madison Avenue, New York 17, N.Y., Tel. MUrray Hill 2-2185
Boyce Nemec, *Executive Secretary*

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OF THE

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- General Precision Laboratory, Inc.
- The Hertner Electric Co.
- International Projector Corp.
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- National Theatre Supply Co.
- Strong Electric Corp.

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- Warner Brothers Pictures

Movielab Film Laboratories, Inc.
National Carbon
National Cine Equipment, Inc.
National Screen Service Corp.
National Theaters Amusement Co., Inc.
Neighborhood Theatre, Inc.
Neumade Products Corp.
Producers Service Co.
Projection Optics Co., Inc.
Radio Corporation of America, RCA Victor Division
Reeves Sound Studios, Inc.
SRT Television Studios
Shelly Films, Limited
Technicolor Motion Picture Corp.
Terrytoons, Inc.
Theatre Holding Corp., Ltd.
Theatre Owners of America, Inc.
Titra Film Laboratories, Inc.
United Amusement Corp., Ltd.
Universal Pictures Co.
Westinghouse Electric Corp.
Westrex Corp.
Wilding Picture Productions, Inc.